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MARS.

PERCIVAL LOWELL.

Spring Phenomena.

In the last paper we watched the polar snows gradually vanish and then the polar sea formed of them in its turn disappear—whither it is the object of this paper to try to discover.

Perhaps the most piquant point about the study of Mars lies in its necessarily detective character. In what the telescope shows us of the planet's surface we stand confronted by an enigma which the eye's evidence alone is quite unable to explain, and to help unravel which, we must perforce call in the brain's ingenuity. We have a case of this before us now. Where has all the water gone is the question. That it has gone is certain; equally certain is it that directly we know neither how nor where. We must therefore do some detective work on the evidence we possess. We shall find, that more lies enfolded in it than we should suspect.

There is a certain peculiarity about the surface markings of Mars which is pretty sure to strike any thoughtful observer with a two or a three inch object-glass—their singular sameness night after night. With quite disheartening regularity each evening presents him with the same appearance he noted the evening before, a dark band obliquely belting the disk and strangely keeping its place in spite of the daily progression of the meridians ten degrees to the east. By attention he will notice, however, that the belt creeps slowly upwards toward the pole. Then suddenly some night he finds that the belt has slipped bodily down to begin again its Sisyphus-like inconclusive spiral climb.

Often as this rhomb-line must have been noticed no explanation of it has ever to my knowledge been given. Yet so singular an arrangement points to something other than chance. Increase of aperture discloses details that corroborate the suspicion of its non-fortuitous character. With sufficient power the continuity of the dark belt is seen to be broken by a series of parallel peninsulas that jut out from the lower edge of the belt, and of long islands parallel to them, all running with one accord in a southeasterly direction and dividing the belt into a similar series of

parallel dark areas. Such are the Mare Tyrrhenum, the Mare Cimmerium, the Mare Sirenum and those unnamed straits that stretch southeasterly from the Auroræ Sinus, the Margaritifer Sinus and Sabæus Sinus. The islands and peninsulas trending in the same direction are, Ausonia, Hesperia, Cimmeria (not down in the particular chart of Schiaparelli's I have given but lying along the middle of the Mare Cimmerium), Atlantis, Pyrrhæ regio, Deucalionis regio and a similar regio below it.

It will further be noticed that these areas curve in general more to the south as they approach the pole.

Now with this fact noted let us return to the water we left standing round the south pole waiting to go somewhere. We may be sure it would not stay there long. No sooner liberated from its winter fetters than it would begin under the pull of gravity to run toward the equator. (It may interest the reader to note that its course would on the spheroidal surface actually be uphill). Each particle would start due north; but its course would not continue in that direction. For at each mile it travelled north it would reach a latitude of greater rotation than the last it left. Its own absolute motion would remain unchanged since there would be nothing to change it; that is it would continue to circle round the globe. But its motion relative to that globe would be very materially altered. As at each latitude it reached, the surface of the planet would spin faster, that surface would, supposing no friction, be constantly slipping away from under it toward the east. The consequence upon the particle would be its northerly motion would be contiuously changing with regard to the surface into a more and more westerly one. If the surface were not frictionless, friction would somewhat reduce the westerly component of the resulting direction but could never wholly destroy it without stopping the particle.

We see therefore that any body, whether solid, liquid or gaseous must in travelling from the pole of a sphere or spheroid necessarily deviate to the west in doing so if the spheroid itself revolves, as Mars does, similarly with our Earth, in the opposite direction.

Now this inevitable trend in direction for anything flowing from the pole to the equator is precisely the trend we notice so conspicuously in the Martian south temperate markings. Here then we have at once a suspiciously suggestive circumstance.

Let us see whether any other facts point in the same direction.

In the opposition of 1877 and its subsequent ones Schiaparelli chronicled a difference at different oppositions in the darkness of several of the above mentioned seas, islands and peninsulas. In

the oppositions that occurred near the time of the summer solstice of the southern hemisphere he observed these seas to be dark, while in the oppositions occurring during its winter solstice they appeared much lighter; and he suggested in conclusion that the modification of tint might have to do with the planet's seasons.

These observations furnished what we may call statical presumption of a seasonal change. At this opposition we have been able at this Observatory to obtain kinematic evidence of such change. We have marked the change progressively take place.

The vernal equinox of the Martian southern hemisphere occurred this year on April 1, the summer solstice of the same hemisphere on Aug. 31st. Now observations were begun here at the end of May, that is at the time of early spring, in that hemisphere of Mars, and a singular fact was at once observed. No trace of any of the peculiar peninsulas I have mentioned was visible. The dark belt stretched unbroken from the Hourglass Sea (Syrtis Major) to the Columns of Hercules. In August when that part of the planet came round into view there was Hesperia as distinct as if it had never been otherwise. That its invisibility at the one time and its conspicuousness at the other was not due to the planet's approach toward us will be seen from the two drawings preceding this article.

Simultaneously with the reappearance of Hesperia the lighter areas in the southern latitudes extended and grew lighter in tint, while the dark areas proportionately decreased in size and became fainter in color.

It will at once be seen how this bit of evidence fits into the other. If the polar sea were thus to descend in a vast freshet toward the equator such are the appearances the freshet might be expected to present. As the water progressed farther and farther north the regions it left behind would gradually dry up, and from having appeared greenish-blue would take on an arid reddish-yellow tint; precisely what is observed to take place.

Another fact of observation is significant. The northern edge of all the seas we have been considering is markedly darker than the rest of them. Now if a current of water were to descend from the pole to the equator the inevitable, constant, deflection to the west which it would suffer would cause it, by the resistance, to change in direction offered by the momentum of the water, to dredge out the northern side of its channel while leaving the southern comparatively flat. So here once more observation and theory are at one. We may therefore conclude that in all probability a great vernal freshet in the most general sense of the term

sweeps every spring from the pole down to the equator, thus disposing of the polar sea and carrying the water into the desert regions about the equator.

Exactly what is the form this freshet takes is more doubtful; whether, that is, it be a true freshet over the surface of the ground or an aerial transference of the water as vapor. Probably neither is the case in its entirety and probably both are true in part. Both would produce greenish-blue areas where the water was and reddish-yellow ones after it had left. For either water itself or vegetation its consequence would show us the first color while deserts would show the last. The configuration of the seas would likewise be explicable on either hypothesis. It would merely be a question of present seas or past sea-bottoms. For air currents would of themselves have been impotent to cause such troughs since there would be nothing, on a perfectly smooth spheroid, to determine their selection for a descent of any one longitude rather than another. The valleys once formed, however, the air currents would follow them and the precipitation taking place in consequence would render them more fertile than the ridges between.

Seas, therefore, past or present, it seems proper to consider them. Whether now they be water surfaces in whole or part or simply the best watered parts of the planets is matter of conjecture. There are facts which point each way, some of which we shall consider in subsequent papers. The probability is that these areas are in part water, in part fertile land. But whatever hypothesis we adopt as to their present condition, one thing the changes in their appearance show unmistakeably: that Mars is a living world. Not a dead inert body such as our Moon so nearly if not absolutely is, but a world, like our Earth, where the years bring round their annual cycle of activity. But in one respect its life differs from that of our Earth; in one that we know of beside probably differing in many others that we wot not of. It has a unity our Earth lacks. No counterpart of this great spring transference of water from the pole to the equator occurs over the terrestrial globe. Some such transference takes place of course on both planets, but on Mars it has a definiteness and a completeness about it that it knows not here. Sufficiently like us to seem in part decipherable Mars is yet sufficiently unlike to baffle the very conjecture it starts. It is this likeness linked to unlikeness in which lies its intellectual charm.

LOWELL OBSERVATORY, Oct. 10th, 1894.

PROGRESS OF ASTRONOMICAL PHOTOGRAPHY.

H. C. RUSSEL.*

I will confine my remarks to a branch of one of our subjects which, within the past twenty years, has done more than anything else to accelerate the progress of our knowledge and to extend our grasp of the grand truths of astronomy. I refer, of course, to the application of photography to the wants of astronomical research. Coming in at first as another possible aid to the observer, it has already shown us that in many cases the observer must stand aside while the sensitive photographic plate takes his place and works with a power of which he is not capable; and I feel sure that in a very few years the observer will be displaced altogether, while his duty will be done by a new sensitive being, not only taking in the visual ray, but also the actinic rays into ultra violet—a being not subject to fatigue, to indigestion, to east winds, to temper, and to bias, but one, above all these weaknesses, calm and unruffled, with all the world shut out, and living only to catch the fleeting rays of light and tell their story.

It has been well said by a very gifted writer† that "the invention of the telescope itself does not mark an epoch more distinctly than the admission of the camera to the celestial armory. All the conditions of sidereal research in especial are being rapidly transformed by its co-operation."

By this new lever the progress of astronomy is being urged forward at a rate which accomplishes more in ten years than was possible in a hundred years by older methods. Its whole life history covers but fifty-three years, and its infancy and youth were cramped by the want of means of existence and growth; but its latter years have been marked by a vigor which has done so much that I shall have little more than time to mark the stepping-stones in that onward march; to trace the details would take volumes.

Fifty-three years ago photography was in the daguerreotype stage, when it was just possible to get a rough photograph of the Moon; forty-three years ago it had reached the collodion stage, and was capable of rendering great aid to astronomy. Its worth had been proved, and the conditions of its successful application to the wants of the astronomer were known, but the enormous

*Government Astronomer at Sidney, Australia. Extract from a recent address.
†Miss Clerke: System of the Stars, p. 23.

value of that power was somehow overlooked. Was it that the innovation was too great to be accepted at once, or that they did not consider the matter sufficiently? If the following record of the slow progress that followed that time and the gradually accelerating progress of the last few years should enlist some other worker into the army of astronomers, it will have done something to add to our knowledge.

It is generally stated that astronomical photography began when, in 1850, Professor Bond succeeded in taking daguerreotypes of the Moon with the great 15-inch refractor at Harvard College Observatory, but there seems to be no doubt that impressions of the Moon were obtained with more or less success some ten years earlier. Professor Henry Draper, of the New York University, writes:*—"The first photographs of the Moon were taken by my father, Professor J. W. Draper, M. D., who published notices of them in his quarto work on the forces of organized plants, and in the *Philosophical Magazine*. The specimens were about 1 inch in diameter, and were presented to the Lyceum of Natural History of New York. They were taken with a photographic lens of 5 inches in aperture, furnished with an eye-piece to increase the magnifying power, the whole mounted on a polar axis and moved by clock-work; the time of exposure was twenty minutes." In September, 1840, he writes:—"There is no difficulty in procuring an impression of the Moon by daguerreotype beyond that which arises from her motion." This was not his first attempt to apply photography to astronnmical work, for he tried in 1834 to fix the lines of the spectrum. The sensitive surface used was bromide of silver as a coating on paper. The experiment was not a success, but it is mentioned in the *Philosophical Magazine* for 1843, "and in the summer of 1842, simultaneously with M. Becqueret, by using daguerreotype plates, I succeeded, and in the following March sent a drawing of the photograph to the *Philosophical Magazine*, and in 1843 I made photographs of the diffraction spectrum by a grating both by reflection and transmission."

Arago announced to the Academie of Sciences at Paris on the 13th of August. 1839,† the great discovery of Niepce and Daguerre, and expressed the opinion that it would be possible to make the Sun and Moon record their own features by photography; and, acting upon this suggestion, Daguerre tried, and failed to get anything more than a very faint impression, from

* Nature, Vol. X, p. 243. Quarterly Journal Science, Vol. 1, p. 381.
† Nature, Vol. XLIV, p. 380.

which all detail was absent. In Arago's *Popular Astronomy* there is reproduced a daguerreotype of the Sun, taken, as stated on it, on April 2nd, 1845, by MM. Foucalt and Fizeau, but no particulars are given. The long exposure of twenty minutes required to get a daguerreotype of the Moon no doubt deterred many who would have tried, and it was only the genius of Bond, coupled with the great refractor, which enabled him to get the first really valuable photograph of the lunar surface. It appears in *Astron. Nachrichten*, No. 1105, that the artists Whipple and Black (of Boston) "for many years before this" had been experimenting whenever they could get the use of the great telescope, and that the earliest successful experiments were made with daguerreotype plates in July, 1850; but the labor and time demanded was so great that he was obliged to put the work aside until he should be able to get improved instrumental appliances. Some of the photographs obtained were taken to England and exhibited at a meeting of the Royal Astronomical Society on May 9th, 1850, again at the meeting of the British Association in September following, and then at the Great Exhibition in 1851; and they were so good that they may be said to have taken the scientific world by storm, but I find at this time no description of what they did show of the Moon's surface. The result might have been anticipated. Everybody who could command a telescope from 4 inches to 6 feet, tried to photograph the Moon with such means as he had, and in one case they induced an astronomer, Mr. De La Rue, to become a worker, and his energy and success did very much to promote the study of astronomical photography. I have said that at the time no measure of what was meant by "good" photographs of the Moon was given, but four years later we find a measure of the term good applied to them. In the British Association Report for 1854, p. 10, the Rev. J. B. Reade, M. A., F. R. S., writes:—"The daguerreotype produced in the Bond refractor possesses a latent sharpness which is difficult to see, but which was brought out by taking a copy of it with a camera. This copy was compared with his own photograph, and he found in both the Mare Crisium with bright surrounding country which separates it from Mare Fecunditatis, and Mare Tranquilitatis, the crater Menelaus, and the ray of light extending from it across the Mare Serenitatis, the semicircular ridge round Mare Imbrium and the unreflective crater Plato,"* so that Bond's picture of the Moon must have possessed a large amount of detail.

* Nature, Vol. XLII, p. 568; also Observatory, Vol. II, p. 13.

Mr. Dancer,* of Manchester, seems to have been the first in England to follow Bond's lead, and in February, 1852, made some sharp pictures of the Moon, using a 4½ inch equatorial. These are believed to be the first taken in England, and were of such excellence that they would bear examination with a compound microscope with a 3 inch objective.

Professor Bond† had not been content with his successful photographs of the Moon. He wished to see what could be done with the stars; and, on July 17th, 1850, Mr. Whipple, under his direction, placed a daguerreotype plate in the focus of the great refractor and obtained the first known stellar photograph—a picture of Alpha Lyræ. The time it took is not given, but it is stated‡ that no image of the pole star could be obtained, no matter how long the exposure was continued, but an elongated image of the double star Castor was obtained before the experiments were given up. At first it seems strange that a picture of the Moon could be taken with comparative ease, while bright stars, which we know are capable of recording themselves in less than one-tenth of the time required for the Moon, required a much longer exposure, and in some cases would not do it at all; but it is obvious that the reason of this is to be found in the imperfection of the clock-work, which, instead of keeping the star image fixed on the one spot on the plate, causes it to wander about that point until the light was too diffused to produce the desired effect.

In 1858§ Dr. Luther, of Konigsberg, showed Mr. De La Rue the daguerreotype of the total eclipse of 1851, which had been taken by Dr. Busch with the Konigsberg heliometer. Considering the state of photography at that time the successful result was remarkable, when due allowance is made for the uncertainty then existing as to the brilliancy of the prominences. Towards the end of 1852 Mr. De La Rue‖ took some photographs with the then new collodion process on glass. He used his 13 inch metallic reflector without clockwork, and naturally met with considerable difficulty, although the time of exposure, ten to thirty seconds, was very short for those days. The work required two persons, and was very tiring, owing to the number of failures. Motion was at first given to the telescope by means of the tan-

* Chamber's Astronomy, third edition, p. 708.

† An Investigation into Stellar Photography, Vol. XI, North American Academy of Sciences.

‡ Astron. Nachrichten, No. 1105.

§ Phil. Trans., 1862, p. 333.

‖ British Association Report, 1859, p. 134, *et. seq.*; also Astronomical Register, 1883, p. 65.

gent screw, and then better results were obtained by putting the sensitive plate in a slide and moving it to follow the Moon's apparent motion. This was done by hand and the amount of motion was determined by looking at a crater through the transparent collodion film, and keeping it bisected by cross wires attached to the back of the plate. Rough as these contrivances seem when measured by modern appliances, Mr. De La Rue succeeded in making some excellent photographs, but, owing to the difficulties, he came to the conclusion to discontinue the work until he should get clockwork to move the reflector.

These photographs were exhibited at a meeting of the Royal Astronomical Society in 1853; they were $1\frac{2}{10}$ inches in diameter, and were considered very good indeed.

It appears‖ that at this time (1853) the possibility of using photography to delineate the surface of the Moon became a burning question with the British Association Committee for the survey of the physical aspect of the Moon, and one of the members, Mr. John Phillips, M. A., F. R. A. S., determined to try what he could do with his own telescope, which had a 6¼-inch Cooke objective and 11 ft. focus. Though, in part, prepared at the beginning of the year, he was not able to make an actual beginning until July, and on 15th and 18th, assisted by Mr. Bates, he obtained some photographs which were exhibited at the British Association meeting September, 1853. The committee thought that they proved beyond a doubt that the research is of a useful and practicable kind, and may be followed up by better things. The images were on collodion plates, and measured 1.2 inches in diameter and were enlarged by an eyepiece in the telescope to 2 inches, and the time of exposure was thirty seconds.

In 1854 the Photographic Society of Liverpool¶ being anxious to show Moon photographs with others of more general character to the meeting of the British Association that year, appointed a committee of the members, of whom Mr. J. Hartnup, the astronomer, was one, to make some lunar photographs for exhibition at the British Association meeting in Liverpool in September of that year.*

* British Association Report, 1853, p. 15.

† British Association Report, 1854, p. 66; also Astronomical Register, 1863, p. 65.

‡ Royal Astronomical Society Monthly Notices, Vol. XV, p. 132.

HINTS FOR A SMALL TELESCOPE.

FLORA E. HARPHAM.

Any one who is willing to spend three or four dollars for lenses may easily become the owner of a small refracting telescope. Four lenses should be purchased, two for the object-glass and two for the eye-piece. In addition to the lenses, a single tube is all that is required theoretically, but in practice the use of several tubes will be found more convenient in making adjustments. The main tube varies in length according to the focal length of the objective and may be formed upon a wooden roller an inch or two shorter than the focal length of the objective and slightly larger in diameter. According to Caroline Herschel's method the tube is made of successive layers of paper smoothly pasted together. For cutting off the outer rays of light from the objective, a tube of half the length and diameter of the first is serviceable, and a very small tube about two inches long will hold the lenses of the eye-piece. In the *Popular Science Monthly* of November, 1883, Dr. Pyburn has given minute directions in regard to the making of such tubes and the packing and cementing of the lenses.

During the past year it has been a part of my duty to assist students who were beginning the study of astronomy and who were making use of these home-made telescopes. I found that even a slight acquaintance with a small glass stimulated interest in the work. The magnifying power of the glass was first tested by Berthon's dynamometer. The mean of ten measures of the diameter of the emergent pencil of light was sixty-seven thousandths of an inch. Since the diameter of the object-glass is one and one-half inches, the quotient of the two gave a magnifying power of twenty-two diameters. By turning the glass upon two pine trees which stood at a distance from the Observatory, the students learned that the telescope gave a complete inversion. From several transits of the Sun the diameter of the field of view was ascertained to be about fifty minutes of arc.

Sunspots have been so numerous during the year that the period of the Sun's rotation was quite well determined from a series of observations. Conspicuous groups, centrally located, were selected and sketched. They were followed to the edge of the western limb, recognized upon their reappearance at the eastern limb and traced to approximately the same central position as at first. One observation gave the time of rotation as $27^d.84$ and another as $27^d.36$. Young's *General Astronomy*

gives $27^d.25$ as the average synodic rotation of the Sun. At the time of these observations sketches were also made of the number, grouping and form of the spots, by means of which the breaking up of the old groups or formations of new ones were noted.

Month by month the Moon furnished a never ending object of interest. The irregularity of the terminator with the depth and startling distinctness of the shadows gave a somewhat adequate conception of the roughness of the Moon's surface. During gibbous and full Moon it was a work of time to establish the identity of the prominent objects on the surface although over sixty craters were located in one evening by one of the observers.

Of course the planets could not compare in interest with the Sun and Moon, but they were frequently observed. Four of Jupiter's satellites were seen and their relative distances from the centre of the planet were estimated in terms of the planet's diameter. The satellites were watched and the changes in their positions showed their revolution around the planet. When the definition was exceptionally good the belts of Jupiter were visible. The motion both of Uranus and Saturn among the stars was ascertained, and in the case of the latter the amount was determined. Saturn and the neighboring stars as seen in the telescope were sketched. The stars were identified on Klein's atlas and the position of Saturn marked on the map. Ten days later a similar sketch was made and from these two positions of the planet the daily motion in right ascension was found to be about one-third of a minute, and in declination about two minutes. A reference to the tables contained in POPULAR ASTRONOMY gives the daily motion for the same time as one-fourth of a minute in right ascension and one and seven-tenths minutes in declination.

Wide double stars and nebulæ offered a field for observation also. Among the stars such wide doubles as ξ Geminorum, δ Boötis and φ Tauri were divided. Of the nebulæ such as 2 Messier near β Aquarii, 8 and 24 Messier on opposite sides of μ Sagittarii, and 6 and 7 Messier not far from λ Scorpii were identified and sketched.

SMITH COLLEGE,
NORTHAMPTON, MASS.

THE FIXED STARS.

W. H. S. MONCK.

V.

The invention of the spectroscope has probably done as much for Stellar Astronomy as that of the telescope itself. The principle of this instrument is well known. It is a combination of prisms increasing the separation of light by a single prism which latter was known at least as far back as the time of Sir Isaac Newton. It was then discovered that in the majority of cases light when passed through a prism produced a very enlarged image which exhibited different colors in different parts. For white light these colors according to Newton consisted of red, orange, yellow, green, blue, indigo and violet in that order. It was not until considerably later that it was found that some sources of light produced one or more bright bands instead of this continuous spectrum, and still later it was found that these bright bands indicated that the light came from a gas instead of from a solid or liquid body. The system of bright bands too was found to be different for each gas so that where light came from a gaseous source we could tell the kind of gas by passing the light through a prism. Fraunhofer in the present century noticed and indicated the position of a number of *dark* lines in the spectrum of the Sun and of some other substances; but it is less than half a century since the discovery was made that gases absorb the same kind of light which they emit. Dark lines in the spectrum of a solid body thus indicated that it had passed through a gas on its way to us; and with the aid of the spectroscope we were able to determine the kind of gas. The terrestrial atmosphere of course has been traversed by all light that reaches us. Lines derived from this source must always exist in the spectra of the stars. They will be most faint when the rays traverse the smallest stratum of atmosphere—in other words when the source of light is in the zenith; and they will be strongest when the source of light is nearest to the horizon. This fact, even if we did not know the composition of the terrestrial atmosphere, would enable us to distinguish the lines caused by it from those produced by the atmosphere of the Sun or star. The existence of solar and stellar atmospheres is thus established beyond the possibility of doubt. The Sun and many other stars afford plain indications of the presence of iron vapor—iron reduced to the gaseous state by in-

tense heat—in their atmospheres. Hydrogen is still more universally present. Some of the most conspicuous lines in the Sun's atmosphere are due to the presence of sodium vapor. Numerous other terrestrial elements which are not found in the Earth's atmosphere have been traced. Of course in this way we can only trace the composition of the Sun's or star's *atmosphere*. The source of light which lies below this atmosphere seems to be solid or fluid, but the question whether gas under very high pressure may not give a continuous spectrum like a solid requires further investigation. If so the source of light—the photosphere as it is called—may be gaseous; but we cannot ascertain the composition of this gas.

The spectrum really extends to a considerable distance beyond the visible limits on both sides. Beyond the red end a delicate instrument will obtain plain indications of heat. An extension beyond the violet end can be easily photographed and dark lines traced on it as well as on the visible part. Nay by passing the invisible rays at this end of the spectrum through certain transparent solutions we can actually convert them into visible rays.* I have already noticed that when a body is so far heated as to become luminous, it at first produces red light only and that as the temperature increases orange light, yellow light, green light etc., spring up in succession. The fuller statement however is that when heating commences the dark rays beyond the red end of the spectrum can just be detected by a sensitive thermometer or some other instrument for measuring heat. Still remaining dark they approach nearer and nearer to the red end as the temperature rises; then red light springs up; then orange, and so on until we reach the violet extremity. Heat the body still more highly and the photographic rays beyond the violet end will appear, and these will gradually extend further and further beyond the violet end as the temperature continues to rise until we reach a point which probably can not as yet be determined. It will thus be seen that the temperature or degree of luminosity of a star may be inferred from the character of its spectrum. But it seems to be pretty certain also that the luminosity of stars is closely connected with the kind of dark lines which we find in

* The late Professor Tyndall maintained that the dark heat rays could also be converted into visible rays. But what seems to have happened in the cases to which he refers is that dark heat-rays when sufficiently concentrated can be made to *produce* visible rays. On the other hand solutions of quinine, etc., seem to render visible *the very same rays* that were previously invisible at the violet end of the spectrum. I am not aware however whether these fluorescent rays (as they have been called) have been tested for the dark lines discovered spectroscopically in that part of the spectrum.

their spectra. There is reason to believe that the hottest and brightest stars exhibit no known dark lines in their spectra except those of hydrogen, but along with the hydrogen lines there are others which cannot be identified with any terrestrial element. Stars of this class are unusually plentiful in the constellation of Orion, which probably owes its brilliancy to this cause, the stars being apparently very distant, Rigel is the brightest of them. (The spectrum of Betelgeuse belongs to a totally different type.) Next comes a class of stars which show hardly any lines except those of hydrogen of which Sirius is usually regarded as the type. After this the lines of a number of other terrestrial elements such as iron, sodium, magnesium, etc., appear along with those of hydrogen. In some stars these lines are much more numerous than in others and in certain cases the lines become bands. It is not however certain that the increased number of lines, or the substitution of bands for lines, indicates a lower temperature or diminished luminosity. The Sun's spectrum exhibits a vast number of lines belonging in great part to terrestrial elements. Stars which exhibit this kind of spectrum are consequently often referred to as solar stars in contradistinction from Sirian stars. Both classes however require subdivision. The Orion stars differ from those of the type of Sirius. The solar class may be divided into two sub-classes which resemble Capella (or Procyon) and Arcturus respectively. These classes embrace the vast majority of the stars, but there are some which cannot be thus classified. A certain number of stars for instance exhibit bright lines in their spectra. Stars of the latter kind seem to be usually variable in their light, but why has not been clearly explained. The meaning of bright lines however is sufficiently obvious. The atmosphere of the star in question is hotter, or at least more luminous, than the solid or fluid background. Supposing that the two were equally luminous we should have no line bright or dark. The absence of any line or series of lines. therefore, in the spectrum of a star does not prove the non-existence of the corresponding element. But when the line appears, whether bright or dark, we know that the gas corresponding to it is there. A supposed bright line however may be the result of absorption at both sides of it. For this reason dark lines can be relied on with greater confidence as indicating the presence of the corresponding element. But if the bright line varies in intensity at different times it is most natural to refer it to a gas whose temperature varies. When this occurs with a variable star, if the bright line was caused by absorption at both sides we would expect to find the

line best defined when the star's light was at a minimum; while if it arose from a glowing gas the line would come out most strongly at the maximum. The latter seems usually to be the case.

Of the stars whose spectra have hitherto been examined rather more than one-half are Sirian and somewhat less than one-half solar, the number which cannot be reduced to either class being (as already intimated) small. Now one important fact has recently been discovered. Comparing Sirian and solar stars of the same magnitude and taking in any considerable number of both, the proper motion of the solar stars is much greater than that of the Sirians. The exact proportion has not as yet been ascertained, but there can be no doubt of the general fact. The proper motion of the solar stars is probably not less than double that of the Sirians of the same magnitude. There are but two possible explanations of this. Either the solar stars are moving through space with greater velocity than the Sirians. or else they are nearer to us (the magnitudes of both being supposed equal). There are reasons besides the color of the light for preferring the latter hypothesis. One of these is afforded by the measurement of velocities in the line of sight, to be explained hereafter. Another, also to be explained hereafter, depends on the orbits of double stars compared with their magnitudes and spectra. A third depends on the effect of the Sun's motion in space. If solar stars were moving with much greater velocity than Sirians, the effect of the Sun's motion on their motions would be less sensible. As far as I can ascertain there is no such difference, but it is to be remembered that the stars used in determining the Sun's motion in space have hitherto been chiefly of the solar type. I think we may therefore lay down with some confidence that the greater proper motions of solar stars are mainly, at least, due to their greater vicinity. Our researches on parallax are as yet too defective to throw much light on this problem. So far as they go, however, they tend to confirm the conclusion otherwise arrived at. Sirius itself is almost the only Sirian star with a sensible parallax. Vega must, I think, now be struck out of the list, but perhaps Altair is to be added to Sirius. α Centauri, 61 Cygni Procyon and various others, which have certainly or probably sensible parallaxes, are solar stars. In the late Oxford results the average parallax for the Sirian second magnitude stars is about 0.05″, while that for the solars exceeds 0.07″. There is reason to think that the real disproportion is greater than this. A Sirian star is probably on the average twice as distant as a solar star

of the same magnitude. Since the quantity of light varies inversely as the square of the distance this amounts to stating that Sirian stars are on the average four times as bright as solars. This may arise either from their presenting a greater extent of luminous surface or from their surfaces being more intensely illuminated. Possibly both causes combine. Cooling is usually accompanied by contraction, so that the diminution of the surface and the reduction of its brightness would go hand in hand. At the same time we must not conclude too hastily that solar stars are cooled-down Sirians. They may be stars of different chemical composition. With the exception of hydrogen there is little evidence of the identity of the elements of which the two classes are composed. If we take the subdivisions already indicated the Orion stars appear to be the most brilliant and consequently most distant when the magnitude is the same. Next come the ordinary Sirians; then the Arcturians and last of all the Capellans which are therefore the nearest to us the magnitudes being equal.

These considerations partly revolutionize the ideas of the structure of the heavens which we would naturally form in the first instance. Assuming that 50 per cent of the stars hitherto examined are of the Sirian and 45 per cent of the solar type (Miss Clerke's estimate) we are to bear in mind that the former are on the average twice as distant as the latter (the range in magnitudes of those which we have examined being about the same for both classes), and therefore if the distribution was uniform ought to be eight times as numerous. Supposing that of the 1,000 brightest stars 500 are Sirian and 450 solar, the latter are probably comprised in a sphere whose radius is only one-half of that which includes the former; and for equal spheres solar stars instead of being less numerous than Sirian are probably about seven times as numerous. So far as our own nearer neighbors among the stars are concerned I think this estimate is not very far from the truth. But this may arise from the Sun being one of a group or cluster consisting chiefly of solar stars, and beyond this group the proportions of solar and Sirian stars may be reversed. The grounds hitherto assigned by believing in such a reversal, however, seem to me unsatisfactory, and the distribution of Sirian and solar stars beyond the distance of say 25 (of my units) must be regarded as an unsolved, though probably not an insoluble, problem in stellar astronomy.

A further indication of the higher temperature and greater luminosity of the Sirian stars is afforded by photography. The rays near the blue or violet end of the spectrum and beyond that

end possess much more photographic power than those nearer to the red end. Now if we compare the photographs of a Sirian and a solar star which to the eye are of the same magnitude, we find that the photographic effect of the former is much greater than that of the latter. Red stars have the least photographic effect and would therefore seem to stand lowest in the scale of luminosity; but this conclusion is not borne out by an examination of the proper motions of the stars, yellow stars often apparently standing lower in the scale than red ones. The position of red stars as regards distance from us is not as yet well determined, but that the white or bluish-white stars of the Sirian or Orion type are on the average more distant than any other stars of the same magnitude cannot, I think, be doubted. The photographic peculiarity already referred to may enable us to determine roughly the spectra of stars which are too faint for our existing spectroscopes. The stars in the galaxy as a rule seem to possess high photographic power, whence they are concluded to be Sirians. But if we are on the average able to see Sirian stars at double the distance of solars, we are probably able to photograph them at treble the distance—which if the distribution was uniform would make them appear to be twenty-seven times as numerous relative to the Solar stars as they really are. If assuming the chemical composition of the two classes of stars to be the same, it seems strange that the hottest and most luminous bodies give evidence only of the presence of the lightest and finest gases such as hydrogen in their atmospheres. These lines are what we might expect the Sun to present after cooling down till the iron, sodium, calcium, etc., vapors had been condensed. But most probably the luminous surface—the photosphere—resembles terrestrial clouds rather than the solid or fluid surface of the Earth. Supposing that our clouds were luminous and were observed by an inhabitant of the Moon, then if the terrestrial atmosphere included a great number of gases it is probable that the light coming from the higher clouds would exhibit the lines belonging to the lighter gases almost exclusively, while many other lines would appear in the spectra of clouds formed at lower levels. The phenomena of sunspots, which seem to be depressions in the photosphere in which gases exist, point towards a cloud-like character in the photosphere itself; which conclusion is confirmed by the low specific gravity of the Sun. The light of Sirian stars very probably comes from clouds at high levels, and that of solar stars from clouds at lower levels; but, of course, these differences of cloud-formation may depend

upon the differences in the chemical composition of the star. We have in some instances reason to believe that Sirian stars possess a very small density—that is taking the volumes of the star to be the volume comprised within its photosphere. This is what might have been expected from a photosphere of high-level clouds. If the star cooled, the clouds would probably sink and the lines of heavier gases would begin to appear in its spectrum. But the last process might be the reverse of this. It would arise from the condensation of some of the heavier gases after the clouds had sunk nearly to the lowest, or perhaps broken up and afforded us a glimpse of the glowing surface of the star itself. The lines belonging to these condensed gases would die out of the spectrum, and if the light of the star did not become too faint for observation its spectrum would probably exhibit the lines of permanent gases only. And considering the large amount of light absorbed by the stellar atmospheres it is not improbable that the condensation of vapors in these atmospheres might produce for a time at least an increase in the brilliancy of the light. This approach of the spectrum of the star at an early stage to the spectrum at a very late stage (supposing the process of cooling to be continuous) may account for the similarity which is found in many instances between the Sirian and the Capellan spectra—the same stars being sometimes referred to the former of these types by one spectroscopist and to the latter by another. As regards proper motion, however, the Capellans stand at the opposite extreme from the Sirians.

It should be borne in mind, however, that all classification of stellar spectra is to a certain extent arbitrary. The distinction between Sirian and solar stars is not like that between cattle and sheep but like that between different kinds of dogs. A typical greyhound, mastiff, bull-dog and spaniel, have but little resemblance to each other, but we meet with dogs which completely bridge over the chasm. With any system of classification there will be some stars whose position is intermediate or doubtful—for the various classes run into each other by imperceptible degrees. Supposing that the various types of spectra were brought about first by the formation of high-level clouds and then gradual sinking as the star cooled, we must expect to meet with stars whose spectra represent every possible stage of this process; or supposing that the difference is rather one of the chemical composition we must equally expect to find stars with a chemical composition intermediate between that of any two stars which we select as presenting typical spectra.

I have spoken of cooling down because stars are known to be radiating a large amount of heat into space, and so far as we have hitherto traced, the amount of heat which they receive by radiation from space is comparatively small. Nevertheless I am far from thinking that a cooling process goes on continuously after the first position of equlibrium under the counter-forces of heat and gravitation has been attained. The heat radiated away by the stars cannot, I apprehend, be lost to the Universe. If the parts of the Universe nearest to us are losing heat, other parts must be gaining it. But I see no reason for thinking that the parts of the Universe nearest to us *are* losing heat. They may have other ways of gaining heat from without than by means of radiation. We are, I think, at all events driven to this alternative —either there is no loss of heat in the ponderable matter throughout the Universe, or else the ether absorbs heat and is in the process of changing its properties owing to the heat thus absorbed. I am speaking of heat given out or derived from without as distinct from heat due to condensation. This latter is now known to be conversion of one kind of motion into another, and there is no difficulty in supposing that the total amount of the latter kind of motion throughout the Universe is being increased at the expense of the former kind. Condensation—by which in the present instance I mean any closing up of the particles of matter of the nature of a collision—may maintain, in part at least, the temperature of a body which is radiating a much larger quantity of heat into space than it receives back from space; but the problem to which I invite the attention of astronomers is, what becomes of the heat which is radiated into space by the Sun and the stars? Till that problem is solved we have no reason for alleging that the Sun or any other star would cool down continuosly even if we supposed the action of gravitation to be altogether suspended. Dark stars, if we may give that name to dark bodies in space, no doubt absorb some of it, but I do not think they can account for the whole. Considering the enormous temperature of the vast number of stars within reach of our telescopes, an equalization of temperature all around would probably render all bodies luminous and make the Earth uninhabitable. As molar motion is often converted into the molecular motion of heat, is it not possible that there is a counter-process going on in which molecular motion becomes molar motion, and stars are consequently found travelling through space with velocities too great to be explained by gravity? But the science is hardly ripe for speculations of this kind as yet.

ATTEMPTS TO PHOTOGRAPH THE SUN.

W. W. PAYNE.

We have not before given attention to the study of the Sun, in this publication, mainly because we were not quite ready to do so. However, we are now able to begin a series of papers on this theme by the aid of some astronomers who have for years given special attention to different branches of solar study. We expect to make the series practical and useful so as to interest the popular reader as well as the general student of astronomy.

In his admirable little book, "The Sun," Professor C. A. Young has divided this topic into four parts, and he has so well defined them that we adopt his own language nearly. These divisions are:

1. *The central portion of the Sun* "which is probably, for the most part, a mass of intensely heated gases."

2. *The surface of the Sun*,—that which is seen by the aid of the telescope. This part is called the photosphere, a word meaning that from which the light emanates. "It is a shell of luminous clouds formed by the cooling and condensation of the condensible vapors at the surface where exposed to the cold of outer space.

3. Above and intermingled with this visible surface is a shallow stratum "composed mainly of incondensible gases (conspicuously hydrogen) left behind by the formation of the photospheric clouds, which bears something of the same relation to them that oxygen and nitrogen of our own atmosphere do to our own clouds." This part is called the chromosphere of the Sun on account of its brilliant scarlet color.

4. The pearly white halo surrounding the Sun and seen in times of total solar eclipses is called the corona. Near the Sun it is exceedingly bright, making a beautiful background for the crimson prominences that flame up through it from the chromosphere below. The detailed structure of the inner corona by the aid of a small telescope is seen to be wonderfully complex and astonishingly beautiful. It is made up of filaments which radiate outward from the Sun's surface generally, but sometimes they are curved and mingled apparently in the most intricate way possible. These thread-like filaments often blend into streaks and striæ which, in turn, together in a confused bundle stretch outward in a few long streamers varying in distance from one to three or more solar diameters. The great streamers gradually and imperceptibly fade out as distance from the Sun increases

until they are lost in the light of the surrounding sky. The corona of the Sun in a total eclipse is one of Nature's sublime and most awe-inspiring pictures ever revealed to the eye of man. Once seen it can never be forgotten. How it is made or what causes it is not known, although astronomers have studied and worked long to unravel the mystery. Its appearance to the naked eye and in the telescope is well known because illustrations of it are found in all elementary books on astronomy. Later we will give some fine plates showing the corona in recent total eclipses in connection with their observation and methods of study.

As the time of duration of a total solar eclipse can not much exceed seven minutes for any one locality (often much less than that), it is plain that the opportunity for observation is very limited indeed, and hence knowledge of the corona has necessarily advanced very slowly. On this account astronomers have been searching long for some method of observing the corona without the aid of a total eclipse. This line of work is the subject of an elaborate paper recently prepared by Professor George E. Hale, director of Yerkes Observatory of the University of Chicago. We here give an extract from it which will furnish our readers the fullest information about it we know within the narrow limits at our disposal.

"The search for a method to render the corona visible to the eye, or to secure its image upon a photographic plate, without the aid of a total eclipse, has been prosecuted for many years. Professor Langley has observed the Sun from the slopes of Mount Etna, from Pike's Peak* and from Mount Whitney, but even when the atmospheric conditions were at their best he could see nothing of the true corona. At Mount Whitney the sky was of a deep violet blue, and absolutely cloudless, with only a slight orange tint about the horizon at sunset. "Carrying a screen in the hand between the eye and the Sun, till the eye is shaded from the direct rays, it can follow this blue up to the edge of the solar disk without finding in it any loss of this deep violet or any milkiness as it approaches the limb. It is an incomparably beautiful sky for the observer's purpose, such as I have not seen equalled in the Rocky Mountains, in Egypt, or on Mount Etna. . . . I found that I could choose a position on the north of the cliff, along whose edge the Sun was moving nearly horizontally; so that the shadow was fixed as regards the observer, and so sharp that, though I must have been over one-quarter of a mile from the portion of the

* *Reports on the Total Solar Eclipses of July 29, 1878, and January 11, 1880*, p. 207.

cliff casting it, I could, without moving from my place, and by only a slight motion of the head, put the eye in or out of view of the Sun's north limb. The rocks were, in these circumstances, lined with a brilliant silver edge, due to diffraction. This I had anticipated, but now I saw what could not be seen by screening the Sun with a near object, that the sky really did not maintain the same violet blue up to the Sun, but that a fine coma was seen about it of about 4° diameter, nearly uniform, though it was sensibly brighter through the diameter of 1½°. Upon bringing to bear upon it an excellent portable telescope, magnifying about thirty times, I found it was composed of motes in the sunbeam, between the diffracting edge and the observer's eye. This result, if disappointing, is also interesting in another point of view, as showing that the dust-shell, which, as I have elsewhere stated, encircles our planet, exists at an altitude of at least 13,000 feet, and under favorable conditions for the purity of the atmosphere."* Other unsuccessful attempts to observe the corona without an eclipse have been made by Professor Bond in the Alps, Dr. Copeland† at Puno at a height of 12,040 feet, Professor Tacchini on Mount Etna, and Professor Todd on Fuji-san. Professor Wright has tried various colored media in the hope of rendering the corona visible, and Professor Harkness‡ and Dr. Pupin§ have devised special apparatus for the same purpose. But the most serious attempt to solve the problem is that of Dr. Huggins, and this calls for more detailed consideration.

"After trying in vain a variety of optical devices, including the crossed prisms afterward employed by Harkness and Deslandres, Dr. Huggins decided to avail himself of the power of the photographic plate to render visible smaller differences in brightness than are directly perceptible to the eye. By experiments in the laboratory he satisfied himself 'that under suitable conditions of exposure and development a photographic plate can be made to record minute differences of illumination existing in different parts of a bright object, such as a sheet of drawing paper, which are so subtle as to be at the very limit of the power of recognition of a trained eye, and even, as it appeared to me, those which surpass that limit.'‖ Professor Schuster's photographs of the coronal spectrum obtained at the eclipse of May 17, 1882, showed a maximum brightness between G and H, and it seemed

* S. P. Langley. *Report of the Mount Whitney Expedition*, p. 41.
† *Copernicus*, vol. III, p. 212.
‡ *Bul. Phil. Soc. of Washington*, vol. X, p. 13.
§ *Astronomy and Astro-Physics*, vol. XII, 1893, p. 362.
‖ *Proc. Roy. Soc.*, vol. XXXIV, 1882, p. 411.

not improbable that an exclusive use of this portion of the spectrum might make it possible to photograph the corona without an eclipse. Later a further argument in favor of the employment of this part of the spectrum was found in the results of Professor Vogel's measures of the absorption of the photospheric light at the center and limb of the Sun. It was discovered that the violet suffered much more absorption than the red, the percentage brightness at the limb compared with the center of the disk being 13 and 30 respectively. As most authorities agree that the rapid increase in absorption toward the limb would indicate that the absorbing gas rises to no great height above the photosphere, the light of the corona, which lies outside the low region of absorption, would reach the Earth without undergoing this absorption. Thus it should be relatively rich in the violet, when compared with the photospheric light which is scattered in our atmosphere.* The advantages offered by photography, especially for work in the more refrangible region of the spectrum, were thus sufficient to lead to its substitution for the visual methods previously employed.

"In 1884 a committee appointed by the Royal Society sent Mr. Ray Woods to the Riffleberg, near Zermatt, for the purpose of continuing Dr. Huggins' experiments at an elevation of 8,500 feet. In spite of the continued presence of a great aureole around the Sun, due to the presence of minute particles of matter in the higher regions of the atmosphere, Mr. Woods obtained coronal images which were very much alike on the same day, but showed variations when separated by longer periods. The use of a disk to cover the Sun's image seemed to be of no advantage. The best results were obtained on the clearest days.†

"During the next two years no experiments in this direction were made in England, owing to the prevalence of whitish skies. In 1886, however, the method was put to the test at the time of the total eclipse of that year. Captain Darwin photographed the Sun on the day before the eclipse, but the coronal images obtained showed no similarity with the true coronal images photographed during totality. On the day of the eclipse exposures made during the partial phases showed a false corona, part of which was in front of the Moon. In no case did the images show the Moon eclipsing the corona. Instantaneous exposures made during totality gave no trace of the corona. Although the conditions were most unfavorable during this eclipse Captain

* *Proc. Roy. Soc.*, vol. XXXIX, 1885, p. 111.
† *Observatory*, vol. VII, 1894, p. 378.

Darwin concludes 'that the result tends to show that a *practical* method of obtaining photographic records of the corona during sunlight is not likely to be obtained,' at the same time remarking that he does not consider it proved that the method is impossible.*

"At Cape Town Dr. Gill photographed the partial phases of the same eclipse with a Huggins coronagraph, but the results were equally disappointing. A long series of experiments made at the Cape Observatory with the coronagraph has not led to results of a definitive character.† Nor have the attempts in this direction of Dr. Lohse,‡ Herr von Gothard§ and M. Deslandres‖ resulted more satisfactorily.

"Professor Tacchini's observations on Mount Etna in 1876¶ led to the establishment of the Bellini Observatory at the base of the great crater a few years later. With a Huggins coronagraph constructed by Grubb, Professor Riccò has made a large number of photographs of the Sun's surroundings. Many of these show distinct coronal forms, extending to great distances from the solar limb. During the partial eclipse of April, 1893, Professor Riccò made several exposures, but the coronal forms shown on the negatives cross the dark body of the Moon without interruption, thus demonstrating that they do not represent the true corona.* Moreover, the exposures with which these and other coronal images have been secured are much shorter than those given with similar instruments during total eclipses. It is universally admitted that the corona at a distance of a solar radius from the limb is much fainter than the Moon. In Professor Riccò's photographs, which were made with an exposure of less than half a second, the coronal forms extend to a distance of nearly a solar diameter. Using the same apparatus and equally sensitive plates we obtained no traces of the Moon (which was well past its first quarter) with an exposure of four seconds, during our recent expedition to Mount Etna. It is, therefore, highly probable that the coronal images obtained with the Huggins apparatus on Mount Etna were of terrestrial origin.

* *Proc. Roy. Soc.*, vol. XLI, 1886, p. 470.

† *Report of H. M. Astronomer at the Cape of Good Hope for the period 1879, May 26, to 1889, July 21*, p. 9.

‡ *Astronomische Nachrichten*, vol. CIV, 1883, p. 209.

§ Von Konkoly's *Himmelsphotographie*, p. 229.

‖ *Comptes rendus*, Jan. 23, 1893.

¶ *Memoire della Societa degli Spettroscopisti Italiani*, vol. V, 1876, p. 151.

* *Memorie della Societa degli Spettroscopisti Italiani*, July, 1893.

PLATE XI.

THE CORONAGRAPH ON PIKE'S PEAK.

POPULAR ASTRONOMY, No. 13.

"During Professor Tacchini's visit to Chicago in August, 1893, I discussed with him the problemof coronal photography, and described our unsuccessful expedition to Pike's Peak. His observations made on Mount Etna had convinced him that the Bellini Observatory (altitude 2942^{m}) would be a suitable place for the continuation of my experiments, especially as the 12-inch equatorial, mounted under an excellent dome, would serve admirably to carry the apparatus. The cordial invitation which he extended on the part of Professor Riccò and himself led to our decision to make an expedition to Mt. Etna in the spring or summer of 1894.

"It had been my intention to employ on Mount Etna the apparatus used at Pike's Peak, and some changes were made in it for the purpose of correcting the defects discovered in the course of our previous experiments. But during the winter Mr. Ranyard visited us in Berlin, and was kind enough to propose that I make use of a spectroheliograph to be built by Otto Toepfer, of Potsdam, for the 18-inch reflector of his London Observatory. I take this opportunity to express to Mr. Ranyard my warmest thanks for his kindness in allowing me to design the spectroheliograph as well as to employ it in the work at Mount Etna.

[TO BE CONTINUED.]

RECENT OBSERVATIONS OF THE SATELLITES OF JUPITER.*

WILLIAM H. PICKERING.‡

The following observations were made at the Lowell Observatory, and have, of course, no connection with the Arequipa work, although made by the same observer. Two years ago I first described the peculiar phenomena which the satellites of Jupiter present, phenomena which are characteristic of them, and which distinguish them from all other bodies in the solar system as far as we are at present aware. Yet apparently these observations have been confirmed at no other Observatory up to the present time. At first sight this may seem extraordinary, but in point of fact it merely comfirms what has already been said of the great advantages for astronomical work which a desert cli-

* Communicated by the author.

‡ This article and the following one were written for *Astronomy and Astro-Physics*. They are both so important and timely that we give them place in this publication also.—*Ed.*

mate possesses, advantages whose magnitude would scarcely be credited by those who have not had an opportunity to test it for themselves. In selecting the location of the Lowell Observatory the point especially insisted on was that the climate should be extremely dry, and the soil arid. Thanks to its location, the "seeing" is seldom as bad as that which is common in moister climates, and this it seems to me is the reason why others have failed to confirm what is apparently perfectly evident here. Thus, from September 9, when the observations began, until the end of the month, when the present series closed, there were but four nights when I was unable to see one or more of these bodies lengthened or shortened, as the case might be, in the manner peculiar to itself,—and two of these nights were cloudy. It is in part to describe some of these newly observed phenomena, and in part to aid others to see the more easily detected features, that the present article has been prepared.

To facilitate my work I have constructed what may be called a scale of ellipticities. Twelve small ellipses of varying excentricity were drawn upon white paper. They were then cut out with all possible accuracy, and pasted upon a piece of black cardboard. The vertical axis of each ellipse measures 10 millimeters. The lengths of the horizontal axes are indicated by the following numbers, which also indicate the arrangement of the ellipses upon the cardboard:

9.6	12.4	12.8
10.0	12.0	13.2
10.4	11.6	13.6
10.8	11.2	14.0

It will be seen that the horizontal diameter of each ellipse exceeds that of its predecessor by 0.4 millimeters. I have found by trial that by looking alternately at a given satellite and at the scale, that even under unfavorable conditions one may generally be certain which of these ellipses the satellite most nearly resembles. If the satellite is well seen, however, one can mentally divide each of these scale divisions into four parts, and thus determine the ellipticity of the disc to within one per cent of the minor axis. The four longest ellipses are only used for studying occultations and eclipses, the discs of the satellites themselves never reaching such a high ellipticity when unaffected by their primary. It has been found that with a power of 1200 diameters the satellites usually appear more nearly round by about two per cent than with a power of 800, a difference for which we must always make allowance when comparing observations made

with these different magnifications. It is most important in delicate observations of this sort, that the line joining the two eyes should always hold the same position relatively to the major axis of the disc of the satellite. If placed alternately parallel and perpendicular to it, both the position-angle and the apparent ellipticity will be found to vary owing to astigmatism from which no body is entirely free. In my own case the ellipticity of the 1st satellite is about four per cent greater when the line joining my eyes is perpendicular to the major-axis, than when it is parallel to it. The position-angle is also probably shifted through about 5°.

As it would seem that some astronomers are still doubtful about the accuracy of my observations made upon these bodies in 1892, I will describe one made upon September 18 of the present year, which is, I think, of interest for several reasons. At $16^h\ 34^m$ the 18-inch Brashear telescope showed that the 1st and 3d satellites were very near together, and that both of them presented elongated discs, the elongations being nearly at right angles to one another. The 2d and 4th satellites were also slightly elongated, but in different directions. The 12-inch Clark telescope was then turned upon the planet, and the observation repeated without difficulty. I next went to the 6-inch Clark, and was surprised to find that with a power of 400, not only the elongations of the 1st and 3d were easily seen, but even that of the 4th could be detected. I especially noted that the elongations had precisely the same position angles relatively to each other as in the larger instruments. The seeing was very good at the time,—8 on a scale of 10.

Since the elongations occurred in different directions for the different satellites, the appearance clearly could not be due to atmospheric conditions, or to the eye. Since identically the same appearance was seen in three different telescopes, it could not be instrumental; and finally, since the elongation has been seen at different times by at least half a dozen different persons, it cannot be a personal idiosyncrasy.

Besides furnishing another proof of the genuineness of the phenomenon, I think this observation has two other important bearings. First, as showing the relative importance of atmosphere *versus* aperture, for delicate visual observations of this sort. In this same category would be included also studies of planetary surface detail, as distinguished from the examination of very faint objects. In other words, if an observer wishes to study very faint stars he must have a large telescope. If he

wishes to study the neighboring planets and brighter satellites he may use a small telescope, but he must have a very good atmosphere.

Secondly, it is hoped that this observation may encourage possessors of small telescopes to try them on the satellites, and it is possible that they may succeed in verifying what larger telescopes less favorably located have heretofore failed to detect. The test of the adequacy of the instrument and atmosphere is a simple one; it is merely, will the disc of the satellite satisfactorily bear a magnification of 400 diameters? If so, then under the most favorable conditions the ellipticity of the discs of the three larger ones should be capable of detection.

In order to aid those who may feel inclined to pursue this investigation, I have prepared ephemerides for the 1st and 3d satellites. They will be found at the end of this article. Until others have succeeded in perceiving the varying elongations of these bodies, it is evidently useless to predict the shapes for the 2d and 4th, which are much more difficult objects to study.

Returning now to this year's work, upon September 21, an opportunity was offered to repeat my former observation upon the occultation of the 3d satellite behind the dark limb of Jupiter. A very satisfactory series of micrometer measurements were obtained for the determination of the extent and density of Jupiter's atmosphere. The flattening of the satellite due to refraction, as it approached the dark limb of the planet was very evident, and was carefully measured upon the scale of ellipticities. As the satellite set behind the planet, the dark space separating the termination from the dark limb of Jupiter was very marked, and measured about 0″.3 as determined by comparison with the threads of the micrometer. The cusps of the setting satellite seemed well defined and pointed, but the seeing was unfortunately too poor at the time to permit me to see the illumination of the atmosphere of Jupiter by the satellite after it had set as was done in 1892. (Astronomy and Astro-Physics, 1893, p. 395.)

Surface detail has been clearly seen upon the 1st, 3d, and 4th satellites. Upon the two latter its nature seems to be the same as previously designated. Upon the former, in addition to the dark line seen in 1892, the bright equatorial region so-called, has been clearly recognized upon several occasions, even when the satellite was not in transit. In fact in one or two instances it was so conspicuous and easily visible, that it appeared at first difficult to understand why it had not been detected earlier. Further investigation, however, showed that

its form is not that of a belt, as hitherto supposed, but rather that of an elongated bright mass, or possibly two masses, arranged in a plane nearly parallel to the orbit. In certain positions of the satellite these markings are, therefore, very conspicuous, while in others they are invisible. Under the latter conditions the dark line shown in my drawings of 1892 is to be seen. This explains then why I missed the bright regions in my earlier studies of this body, as it was examined for detail upon only a few occasions, and upon those occasions I apparently sketched the satellite's other side! It is thought possible that an independent determination of the period and direction of rotation of this satellite may be obtained by means of these markings, and I hope shortly to undertake this investigation.

In the paper above referred to (ASTRONOMY AND ASTRO-PHYSICS, 1893, p. 392) describing my observations in 1892, two periods were given for the 1st satellite, differing from one another by fifteen seconds, one based on the supposition that the direction of rotation of the satellite upon its axis was direct, and the other considering the direction of rotation to be retrograde. It was stated at that time that observations made at the next opposition would decide between these two periods, as the difference in the time when the circular phase was presented by the satellite would then have amounted to over three hours. At that opposition, however, I was not so situated that I could make the observations myself, and unfortunately no one else succeded in making them. Now it happens that at the end of two years 1321 retrograde revolutions very nearly equal 1320.5 direct revolutions, and by a curious coincidence, the position of the Earth is such at the present time, that the correction which this factor introduces into the computation almost exactly makes up the discrepancy between the two results, so that the round phase of the satellite, upon the theory of direct rotation, would occur upon September 30 at $17^h\ 38^m$ M. M. T., and upon the theory of retrogade rotation upon September 30, at $17^h\ 40^m$ M. M. T. It is therefore quite impossible at present to distinguish between the two periods, by this method. It will be noted that this is the first occasion since 1892 when such an unfortunate coincidence could have occurred.

We will now see how this year's observations of the circular phase of the satellite bears out these predictions. In the following table, both the direct and retrograde theories are presented. The figures in the first column give the observations of the circular phase in 105th meridian time; those in the second the

theoretical times as deduced from these observations, assuming that the rotation of the satellite is direct; those in the third the difference between the two; while those in the fourth and fifth columns give the theoretical times and differences assuming a retrograde rotation:

SATELLITE I.

Observed.	Direct Rotation.		Retrograde Rotation.	
d h m	h m	m	h m	m
Sept. 9 18 12	18 28	+ 16	18 36	+ 24
15 18 14	18 06	− 8	18 11	− 3
17 16 12	15 47	− 25	15 51	− 21
20 15 40	15 37	− 3	15 37	− 3
21 17 46	17 44	− 2	17 43	− 3
23 15 21	15 25	+ 4	15 23	+ 2
24 17 29	17 32	+ 3	17 29	0
30 16 57	17 10	+ 13	17 04	+ 7
Average deviation		± 9m		± 8m

The theory of retrograde rotation best satisfied the observations of 1892. The observations of 1894 indicate a slight advantage in its favor. This advantage would be much more marked, were it not for the first observation, which was made by daylight. The present investigation shows that the circular phase really occurred that morning after the observations had ceased. In a rigorous discussion, it would therefore probably be best that this observation should be discarded, as incomplete. This would reduce the average deviations of an observation on the hypothesis of retrograde rotation to 5m, and would make the most probable time of the last observation, September 30d 17h 07m.

We have already seen that the theoretical time of the circular phase, based upon the observations made in 1892, was September 30d 17h 40m. It should be stated, moreover, that I purposely delayed making this latter computation until all the observations save the last one had been secured, in order that my mind should be entirely unbiased in the matter. On completing the computations, it was satisfactory to note that the accuracy of the observations made in 1892 was sufficient to enable me to compute the time of the circular phase for two years in advance with an error of only 33m.

The recent observations show that a correction of 1s.5 should be applied to the period formerly published. This period was 13h 03m 10s.8 upon the hypothesis of retrograde rotation. The cor-

rected period therefore now becomes $13^h\ 03^m\ 09^s.3$, and is probably correct within $0^s.2$.

The change in shape of the satellite at the time that the circular phase is assumed is quite marked, and much more rapid than at any other period. The name "circular phase," although apparently quite applicable in 1892, does not appear to be so at the present time, since the observations show that the ellipse, although it becomes much shortened, never quite reaches the circular shape. Whether it will do so later remains to be seen. The following series of figures illustrate the nature of a night's observations, and indicate the length of the major axis of the elliptical disc in terms of the minor one:

SATELLITE I.

Date.	Ell.	Date.	Ell.	Date.	Ell.
d h m		d h m		d h m	
Sept. 23 15 06	115	Sept 24 16 25	118	Sept. 24 17 29	108
" " 13	"	" " 34	114	" " 37	"
" " 21	112	" " 39	"	" " 39	"
" " 27	114	" " 45	112	" " 48	109
" " 34	118	" " 51	"	" " 52	110
" " 36	116	" " 57	"	" " 58	112
" " 40	118	" 17 04	110	" 18 04	"
" " 46	120	" " 14	109	" " 11	114
" " 51	119	" " 19	108	" " 29	115
" 16 02	"	" " 24	"	" " 33	116

Theory indicates that the circular phase occured upon September 23, at $15^h\ 26^m$, and upon September 24, at $17^h\ 32^m$.

In the computation of an ephemeris for the 1st satellite we must make use of the following data:—

Period, $13^h\ 03^m\ 09.3^s$
Rotation, retrograde.
Epoch, 1894, Sept. $30^d\ 23^h\ 50^m$.

The period indicates the mean solar interval which elapses from one circular phase to the next but one, as seen from the Sun. The following approximation is a very convenient one, 57 periods equal 31 days. This involves an error in the period of only $0^s.17$, which may be neglected for ordinary purposes. We will continue to assume the rotation retrograde, as that assumption continues to accord best with the observations. The epoch represents the Greenwich Mean Time at which the satellite would have appeared circular as seen from the center of the Sun, had the velocity of light been infinite. To compute an ephemeris, we must al-

low for the time required by light to pass between the satellite and the Earth, and we must also make a correction for the angle between the Sun and the Earth as seen from the satellite. The first correction is always positive, the second is negative before opposition, and positive afterwards.

Since the rotation is retrograde, the sidereal period of the satellite is longer than the solar one. Its length is $13^h\ 03^m\ 15^s.2$. The ephemeris is more quickly computed from its solar period, since the angular distance of the Sun and Earth as seen from Jupiter is given for every other day by Marth, but the sidereal period may be employed if we compute the longitude of Jupiter as seen from the Earth. It is of interest to note that this satellite is one of the few bodies in our system whose period is now known with considerable accuracy. It ranks in order next after Mars.

The following ephemeris gives the Greenwich Mean Times at which the satellite will present the nearest approach to a circular phase as seen from the Earth. The position angle in general varies from 0° to + 12° with regard to Jupiter's equator, but occasionally exceeds these limits, especially when the disc is near its minimum elongation. This position angle is readily measured, but is subject to rapid fluctuations, whose nature I am investigating at the present time, and hope before long to be able to predict.

EPHEMERIS FOR SATELLITE I.

Nov.	1	06	39			14	52			23	07			07	22
		13	10			21	24		16	05	38			13	54
		19	42		9	03	55			12	10			20	25
	2	02	13			10	27			18	42		24	02	57
		08	45			16	59		17	01	14			09	28
		15	16			23	31			07	45			16	00
		21	48		10	06	02			14	17			22	32
	3	04	19			12	34			20	48		25	05	04
		10	51			19	05		18	03	20			11	35
		17	23			01	37			09	52			18	07
		23	55		11	08	09			16	24		26	00	38
	4	06	26			14	41			22	55			07	10
		12	58			21	12		19	05	27			13	42
		19	29		12	03	44			11	58			20	14
		02	01			10	15			18	30		27	02	45
	5	08	33			16	47		20	01	02			09	17
		15	05			23	18			07	34			15	48
		21	36		13	05	50			14	05			22	20
	6	04	08			12	22			20	37		28	04	52
		10	39			18	54		21	03	08			11	24
		17	11		14	01	25			09	40			17	55
		23	42			07	57			16	12		29	00	27
	7	06	14			14	28			22	44			06	58
		12	46			21	00		22	05	15			13	30
		19	18		15	03	32			11	47			20	02
	8	01	49			10	04			18	18		30	02	34
		08	21			16	35		23	00	50			09	05

Nov.	30	15	37	Dec.	8	12	55	Dec.	16	10	14	Dec.	24	07	34
		22	08			19	27			16	46			14	06
Dec.	1	04	40		9	01	58			23	18			20	38
		11	12			08	30		17	05	49		25	03	10
		17	44			15	02			12	21			09	41
	2	00	15			21	37			18	53			16	13
		06	47		10	04	05		18	01	25			22	45
		13	18			10	37			07	56		26	05	17
	2	19	50			17	08		18	14	28			11	48
	3	02	21			23	40			20	59			18	20
		8	53		11	06	12		19	03	31		27	00	52
		15	25			12	44			10	03			07	24
		21	57			19	15			16	35			13	55
	4	04	28		12	01	47			23	06			20	27
		11	00			08	18		20	05	38		28	02	59
		17	32			14	50			12	10			09	31
	5	00	04			21	22			18	42			16	02
		06	35		13	03	54		21	01	13			22	34
		13	07			10	25			07	45		29	05	06
		19	38			16	57			14	17			11	38
	6	02	10			23	28			20	49			18	09
		8	42		14	06	00		22	03	20		30	00	41
		15	14			12	32			09	52			07	13
		21	45			19	04			16	24			13	45
	7	04	17		15	01	35			22	56			20	16
		10	48			08	07		23	05	27		31	02	48
		17	20			14	39			11	59			09	20
		23	52			21	11			18	31			15	52
	8	06	24		16	03	42		24	01	03			22	32

The periodical changes of the 3d satellite are not as yet sufficiently well understood to enable me to give its ephemeries with the same certainty as that of the 1st. It is likely however to be elongated upon or about the following dates:—November 1, 5, 8, 9, 13, 16, 17, 21, 24, 25, and 29. Upon November 5, 13, 21, and 29, itsposition angle will differ materially from the position it will have upon the other dates, possibly at times by as much as 60°.

On account of the comparatively slow motion of this satellite, it will be some weeks before I can connect our present series of observations with those made in 1892. When that is done, however, its motions will be pretty well understood, and it will then be possible to furnish an accurate ephemeris for many months in advance.

LOWELL OBSERVATORY, October 6, 1894.
Flagstaff, Arizona.

THE GREAT RED SPOT AND OTHER MARKINGS ON JUPITER.

E. E. BARNARD.

THE GREAT RED SPOT.

The surface of Jupiter is very strongly marked this opposition by two broad reddish belts, one on each side of the equator, and a broad white belt between them at the equator.

The Great Red Spot is fairly distinct in outline, though quite pale—a feeble red.

The great bay in the south equatorial belt north of the Red Spot is still persistent and well marked.

Following are observations of the central transit of the Great Red Spot and the deduced longitudes (referred to Marth's System II):

	d	h	m		°
1894 Sept.	23	15	46 5	Standard Pacific Time. Longitude	360.9
Sept.	30	16	32.8		360.7
Oct.	7	17	20.0		361.3
Oct.	14	18	3.0		359.4

From these observations, it is apparent that the spot is very closely following the motion assigned to it by Mr. Marth.

The following end of the spot is quite dark. There are white regions on its surface. The belt south of it seems to be in contact with the spot, if it does not actually overlap it slightly.

Small Black and White Spots in the Northern Hemisphere.

In the northern equatorial red belt is a number of very small black red spots. They are very slightly elongated in an equatorial direction. There are also in this belt some small well defined white spots—similar in size and form to the dark ones. Indeed in certain regions of the belt, these black and white spots alternate with decided regularity.

Immediately opposite the Great Red Spot and near each other lie a couple of these objects--a black and a white spot. These are strikingly well defined and easy of observation.

I have selected these for a series of measures to determine their relative motion.

The measures show that the white spot (which follows) is slowly gaining on the dark one; the distance is diminishing about 0″.05 daily. This will bring them together near the middle of January, 1895.

The conjunction of these spots would be a very interesting and important phenomenon, if they were exactly in the same parallel, since an occultation of one or the other must then occur and the result would show us which is uppermost in the Jovian atmosphere. Unfortunately, however, there will be no occultation as the south edge of the white spot is exactly on the same parallel with the north edge of the dark one. They will perhaps graze in passing; it will therefore be interesting to watch the conjunction if they remain sufficiently permanent.

Following are the measures of the distance between their centers when one or the other was in transit.

	d	h	m		
					"
1894 Sept.	23	15	48	Standard Pacific Time.	Distance = 5.82
Sept.	30			Standard Pacific Time.	5.78
Oct.	7	17	5	Standard Pacific Time.	5.32

Reduced to distance 5.20 these become

	"
Sept. 23	5.67
Sept. 30	5.52
Oct. 7	4.97

The small black spot seems to have approximately the same rotation period as that of the Great Red Spot.

TRANSIT OF THE SMALL WHITE SPOT.

d	h	m		°
Sept. 23	15	55	Standard Pacific Time.	Longitude = 366.0

TRANSIT OF THE SMALL BLACK SPOT.

d	h	m		°
Oct. 7	17	0.0	Standard Pacific Time.	Longitude 349.3

Estimated transits of this object on

"

Sept. 23 gave longitude 349.2
Sept. 30 gave longitude 351.0

This and the other black spots, are very similar in appearance and location to the small black spots of 1890 and 1891. See my papers on these objects in *Monthly Notices* R. A. S., vol. LI and vol. LII. The previous spots, however, decreased their longitudes about a quarter of a degree daily.

The customary white spots in the southern hemisphere are as abundant as ever.

These observations have been made while examining the planet with the 36-in. to get early observations of the fifth satellite.

On Sept. 10^d 17^h $1^m.6$ with the 12-inch, another of the small black spots was in transit, and its longitude was $108°.8$.

The great white equatorial belt has been singularly free of markings of any kind. There are now, however, a few dusky markings appearing in it.

MT. HAMILTON, Oct. 18, 1894.

PLANET NOTES FOR DECEMBER.

H. C. WILSON.

Mercury will be morning planet during December and may be seen toward the southeast between six and seven o'clock during the first half of the month. The best observations will be obtained, however, about ten or eleven o'clock when the planet is near the meridian.

We would remind those of our readers, who receive this number of POPULAR ASTRONOMY before Nov. 10, of the transit of Mercury which is to occur on that date. The transit will begin at $9^h\ 55^m$ A. M. and end at $3^h\ 12^m$ P. M. Central time. For other data see last number.

Venus will be evening planet but will set too soon after the Sun to be seen.

Mars will be in excellent position for evening observation. He will be near the meridian between seven and eight, at a good altitude so that, although this is a cold month, some good views ought to be obtained. Mars will be in conjunction with the Moon, about 2° south, Dec. 8 at noon.

The seeing at Northfield has not been of the best this year and we have but few really good views of Mars. Our best view was the night of Oct. 8, when the gulf Auroræ Sinus, longitude 55° was on the Martian meridian, (see Schiaparelli's map reproduced in our last number). The appearance of the planet was quite different in many respects from that indicated by the map. Solis Lacus was not round or oval, but was broader at the east end, agreeing almost exactly with the map drawn by Proctor years ago. The "canals" Ambrosia, Nectar, Tithonius, Fortuna, Chrysorrhoas and Ganges were seen, some of them in slightly different positions from those shown in the map. Fons Juventæ was also seen and a canal, not on the map, running northward from it.

Mare Erythraeum with the light regions Deucalionis Pyrrhæ and Protei appeared much as shown in the map but Mare Australe did not show dark at all. All the south polar region except the snow-cap itself appeared of the same yellowish hue with the north equatorial regions.

The south polar cap was quite small and on Oct. 10 and 12 was still smaller, measuring only a small fraction of a second of arc. On the 16th it had entirely disappeared. Since that time to the present writing (Oct. 23) the snow-cap has been entirely invisible. We do not remember that such a total dissappearance has ever been recorded before, although the great diminution of the polar cap in the summer season has been a well known fact.

Jupiter may be observed during the whole night in December. He will be in conjunction with the Moon, 5° to the south of the latter on the morning of the 13th, and at opposition to the Sun on the 22d. The nights will be cold but a good view of Jupiter's belts well repays the observer for the little suffering that must be endured to get it.

Saturn and *Uranus* are morning planets and will probably not be observed much by the amateur in the cold weather. Saturn is at the feet of Virgo moving slowly eastward. Uranus is in Libra a little south of the star ν.

Neptune may be observed all night. He is in Taurus a little south of the star ι, and moving very slowly westward. Neptune will be at opposition Dec. 6.

Planet Tables for December.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

MERCURY.

Date.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Dec. 5	15 33.4	− 17 31	5 44 A. M.	10 35.6 A. M.	3 27 P. M.
15	16 33.1	− 21 33	6 23 "	10 55.6 "	3 28 "
25	17 38.7	− 24 08	7 02 "	11 21.9 "	3 42 "

VENUS.

Dec. 5	16 54.3	− 22 37	7 34 A. M.	11 56.3 A. M.	4 19 P. M.
15	17 49.0	− 23 51	7 55 "	12 11.4 P. M.	4 25 "
25	18 43.0	− 23 51	8 11 "	12 27.0 "	4 43 "

MARS.

Dec. 5	1 23.3	+ 9 10	1 44 P. M.	8 23.9 P. M.	3 04 A. M.
15	1 31.4	+ 10 18	1 08 "	7 52.6 "	2 37 "
25	1 42.9	+ 11 40	12 34 "	7 24.7 "	2 15 "

JUPITER.

Dec. 5	6 15.0	+ 23 09	5 32 P. M.	1 14.8 A. M.	8 58 A. M.
15	6 09.5	+ 23 12	4 46 "	12 29.9 "	8 13 "
25	6 03.6	+ 23 14	4 01 "	11 44.7 P. M.	7 28 "

SATURN.

Dec. 5	14 06.8	− 10 24	3 47 A. M.	9 9.6 A. M.	2 32 P. M.
15	14 10.6	− 10 42	3 13 "	8 34.0 "	1 55 "
25	14 14.0	− 10 58	2 39 "	7 58.2 "	1 18 "

URANUS.

Dec. 5	14 59.9	− 16 41	5 07 A. M.	10 02.1 A. M.	2 56 P. M.
15	15 02.2	− 16 51	4 31 "	9 25.0 "	2 20 "
25	15 04.2	− 17 00	3 54 "	8 47.7 "	1 42 "

NEPTUNE.

Dec. 5	4 53.1	+ 21 01	4 20 P. M.	11 52.9 P. M.	7 25 A. M.
15	4 51.9	+ 21 00	3 40 "	11 12.5 "	6 45 "
25	4 50.7	+ 20 58	3 00 "	10 32.0 "	6 04 "

THE SUN.

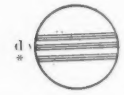
Dec. 5	16 49.0	− 22 27	7 21 A. M.	11 51.0 A. M.	4 21 P. M.
15	17 33.0	− 23 19	7 30 "	11 55.5 "	4 21 "
25	18 17.4	− 23 23	7 36 "	12 00.5 P. M.	4 24 "

Occultations Visible at Washington.

Date 1894	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	IMMERSION Angle f'm N p't. °	EMERSION Washington M. T. h m	EMERSION Angle f't N p't. °	Duration. h m
Dec. 5	B.A.C. 8184	6	8 31	76	9 39	207	1 08
7	70 Piscium	8	11 07	100	12 00	198	0 53
9	27 Arietis	6	3 49	40	4 43	260	0 54
10	9 Tauri	7	8 51	126	9 27	181	0 36
10	*g* Pleiadum	6	13 38	33	14 27	304	0 48
10	17 Tauri	4	13 25	74	14 35	262	1 10
10	23 Tauri	5	14 15	128	14 59	212	0 44
10	24 Tauri	8	14 38	96	15 38	245	1 00
10	η Tauri	3	14 42	99	15 41	243	0 59
10	B.A.C. 1171	8	15 14	57	16 08	287	0 54
10	27 Tauri	4	15 32	128	16 13	217	0 41
10	28 Tauri	6	15 28	107	16 21	238	0 53
13	47 Geminorum	6	17 16	85	18 11	311	0 55
16	34 Leonis	6	15 42	114	16 57	319	1 15

Jupiter's Satellites for December.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I. 

III.

II.

IV. No Eclipse.

Configurations at 11h for an Inverting Telescope.

Day.	West.	East.
1	·3 2·	○ 1· ·4
2	·2	○ ·3 4· ·1●
3	1·	○ ·2 .3 4·
4		○ ·12· 3·4·
5	2· 1·	○ 3· 4·
6	3· 4· ·2	○ 1·
7	3· 4· ·1	○ 2·
8	4· ·3 2·	○ 1·
9	4· ·2 ·1	○ ·3●
10	○1· ·4	○ ·2 ·3
11	·4	○ ·1 2· 3·
12	·4 2· 1·	○ 3·
13	·4 3· ·2	○ ·1
14	3· ·1	○ ·2 ·4
15	·3 2·	○ 1· ·4
16	·2 ·1	○ ·4 ·3●
17	○1·	○ ·2 3· 4·
18		○ ·1 2· ·3 ·4
19	2· ·1	○ 3· 4·
20	3··2	○ ·1 4·
21	3· 1·	○ ·2 4·
22	○2· ·3	○ 4. 1·
23	·24· ·1 ·3	○
24	4·	○ 1··2 ·3
25	4·	○ 2· ·3 1●
26	4· 2· 1·	○ 3·
27	·4 ·2 3·	○ ·1
28	·4 3· 1·	○ 2·
29	·3 4·	○ 2· 1·
30	2· ·1 ·3 ·4	○
31		○·2 1· ·4 ·3

Phenomena of Jupiter's Satellites.

Central Time.

		h	m			
Dec.	1	2	53 P. M.	II	Sh.	In.
		3	57 "	II	Tr.	In.
		5	29 "	II	Sh.	Eg.
		6	33 "	II	*Tr.	Eg.
	2	12	39 A. M.	I	*Sh.	In.
		1	11 "	I	*Tr.	In.
		2	56 "	I	*Sh.	Eg.
		3	27 "	I	*Tr.	Eg.
		3	05 P. M.	III	Ec.	Dis.
		7	51 "	III	*Oc.	Re.
		9	50 "	I	*Ec.	Dis.
	3	12	34 A. M.	I	*Oc.	Re.
		10	03 "	II	Ec.	Dis.
		1	36 P. M.	II	Oc.	Re.
		7	08 "	I	*Sh.	In.
		7	37 "	I	*Tr.	In.
		9	24 "	I	*Sh.	Eg.
		9	53 "	I	*Tr.	Eg.
	4	4	18 "	I	Ec.	Dis.
		7	00 "	I	*Oc.	Re.
	5	4	11 A. M.	II	*Sh.	In.
		5	04 "	II	*Tr.	In.
		6	47 "	II	Sh.	Eg.
		7	41 "	II	Tr.	Eg.
		1	36 P. M.	I	Sh.	In.
		2	03 "	I	Tr.	In.
		3	53 "	I	Sh.	Eg.
		4	19 "	I	Tr.	Eg.
	6	5	12 A. M.	III	*Sh.	In.
		6	54 "	III	Tr.	In.
		7	59 "	III	Sh.	Eg.
		9	42 "	III	Tr.	Eg.
		10	47 "	I	Ec.	Dis.
		1	26 P. M.	I	Oc.	Re.
		11	20 "	II	*Ec.	Dis.
	7	2	43 A. M.	II	*Oc.	Re.
		8	05 "	I	Sh.	In.
		8	29 "	I	Tr.	In.
		10	21 "	I	Sh.	Eg.
		10	45 "	I	Tr.	Eg.
	8	5	16 "	I	*Ec.	Dis.
		7	52 "	I	Oc.	Re.
		5	29 P. M.	II	*Sh.	In.
		6	12 "	II	*Tr.	In.
		8	05 "	II	*Sh.	Eg.
		8	48 "	II	*Tr.	Eg.
	9	2	34 A. M.	I	*Sh.	In.
		2	55 "	I	*Tr.	In.
		4	50 "	I	*Sh.	Eg.
		5	11 "	I	*Tr.	Eg.
		7	05 P. M.	III	*Ec.	Dis.
		11	09 "	III	*Oc.	Re.
		11	44 "	I	*Ec.	Dis.
	10	2	18 A. M.	I	*Oc.	Re.
		12	38 P. M.	II	Ec.	Dis.
		3	50 "	II	Oc.	Re.
		9	02 "	I	*Sh.	In.
		9	21 "	I	*Tr.	In.
		11	19 "	I	*Sh.	Eg.
		11	37 "	I	*Tr.	Eg.
	11	6	13 "	I	*Ec.	Dis.
		8	44 "	I	Oc.	Re.

		h	m			
Dec.	12	6	47 A. M.	II	Sh.	In.
		7	19 "	II	Tr.	In.
		9	24 "	II	Sh.	Eg.
		9	56 "	II	Tr.	Eg.
		3	31 P. M.	I	Sh.	In.
		3	47 "	I	Tr.	In.
		5	47 "	I	*Sh.	Eg.
		6	03 "	I	*Tr.	Eg.
	13	9	11 A. M.	III	Sh.	In.
		10	10 "	III	Tr.	In.
		12	00 M.	III	Sh.	Eg.
		12	41 P. M.	I	Ec.	Dis.
		12	59 "	III	Tr.	Eg.
		3	11 "	I	Oc.	Re.
	14	1	56 A. M.	II	*Ec.	Dis.
		4	56 "	II	*Oc.	Re.
		9	59 "	I	Sh.	In.
		10	12 "	I	Tr.	In.
		12	16 P. M.	I	Sh.	Eg.
		12	28 "	I	Tr.	Eg.
	15	7	10 A. M.	I	Ec.	Dis.
		9	36 "	I	Oc.	Re.
		8	05 P. M.	II	*Sh.	In.
		8	27 "	II	*Tr.	In.
		10	42 "	II	*Sh.	Eg.
		11	03 "	II	*Tr.	Eg.
	16	4	28 A. M.	I	*Sh.	In.
		4	38 "	I	*Tr.	In.
		6	44 "	I	Sh.	Eg.
		6	54 "	I	Tr.	Eg.
		11	04 P. M.	III	*Ec.	Dis.
	17	1	39 A. M.	I	*Ec.	Dis.
		2	25 "	III	*Oc.	Re.
		4	02 "	I	*Oc.	Re.
		3	13 P. M.	II	Ec.	Dis.
		6	03 "	II	*Oc.	Re.
		10	56 "	I	*Sh.	In.
		11	04 "	I	*Tr.	In.
	18	1	13 A. M.	I	*Sh.	Eg.
		1	20 "	I	*Tr.	Eg.
		8	07 P. M.	I	*Ec.	Dis.
		10	27 "	I	*Oc.	Re.
	19	9	23 A. M.	II	Sh.	In.
		9	34 "	II	Tr.	In.
		12	00 M.	II	Sh.	Eg.
		12	10 P. M.	II	Tr.	Eg.
		5	25 "	I	*Sh.	In.
		5	30 "	I	*Tr.	In.
		7	41 "	I	*Sh.	Eg.
		7	46 "	I	*Tr.	Eg.
	20	1	11 "	III	Sh.	In.
		1	26 "	III	Tr.	In.
		2	36 "	I	Ec.	Dis.
		4	01 "	III	Sh.	Eg.
		4	14 "	III	Tr.	Eg.
		4	53 "	I	*Oc.	Re.
	21	4	31 A. M.	II	*Ec.	Dis.
		7	10 "	II	Oc.	Re.
		11	53 "	I	Sh.	In.
		11	56 "	I	Tr.	In.
		2	10 P. M.	I	Sh.	Eg.
		2	12 "	I	Tr.	Eg.

		h	m					h	m		
Dec.	22	9	03 A. M.	I	Oc. Dis.	Dec.	27	4	41 P. M.	III	*Tr. In.
		11	19 "	I	Oc. Re.			5	11 "	III	*Sh. In.
		10	41 P. M.	II	*Tr. In.			6	42 "	I	*Ec. Re.
		10	41 "	II	*Sh. In.			7	29 "	III	*Tr. Eg.
	23	1	18 A. M.	II	*Tr. Eg.			8	02 "	III	*Sh. Eg.
		1	19 "	II	*Sh. Eg.		28	7	06 A. M.	II	Ec. Dis.
		6	22 "	I	Tr. In.			9	23 "	II	Oc. Re.
		6	22 "	I	Sh. In.			1	39 P. M.	I	Tr. In.
		8	38 "	I	Tr. Eg.			1	48 "	I	Sh. In.
		8	38 "	I	Sh. Eg.			3	55 "	I	Tr. Eg.
	24	2	52 "	III	*Oc. Dis.			4	04 "	I	Sh. Eg.
		3	29 "	I	*Oc. Dis.		29	10	47 A. M.	I	Oc. Dis.
		5	45 "	III	Ec. Re.			1	11 P. M.	I	Ec. Re.
		5	45 "	I	Ec. Re.		30	12	55 A. M.	II	*Tr. In.
		5	48 P. M.	II	*Ec. Dis.			1	18 "	II	*Sh. In.
		8	16 "	II	*Oc. Re.			3	32 "	II	*Tr. Eg.
	25	12	47 A. M.	I	*Tr. In.			3	55 "	II	*Sh. Eg.
		12	51 "	I	*Sh. In.			8	05 "	I	Tr. In.
		3	03 "	I	*Tr. Eg.			8	17 "	I	Sh. In.
		3	06 "	I	*Sh. Eg.			10	21 "	I	Tr. Eg.
		9	55 P. M.	I	*Oc. Dis.			10	33 "	I	Sh. Eg.
	26	12	14 A. M.	I	*Ec. Re.		31	5	13 "	I	*Oc. Dis.
		11	48 "	II	Tr. In.			6	02 "	III	Oc. Dis.
		11	59 "	II	Sh. In.			7	40 "	I	Ec. Re.
		2	25 P. M.	II	Tr. Eg.			9	46 "	III	Ec. Re.
		2	37 "	II	Sh. Eg.			8	23 P. M.	II	*Ec. Dis.
		7	13 "	I	*Tr. In.			10	30 "	II	*Oc. Re.
		7	19 "	I	*Sh. In.	Jan.	1	2	31 A. M.	I	*Tr. In.
		9	29 "	I	*Tr. Eg.			2	45 A. M.	I	*Sh. In.
		9	37 P. M.	I	*Sh. Eg.			4	47 "	I	*Tr. Eg.
	27	4	21 "	I	Oc. Dis.			5	02 "	I	*Sh. Eg.

NOTE.—In., denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse. Oc., denotes occultation; Tr., transit of the satellite; Sh. transit of the shadow; * Visible at Washington.

Phases and Aspects of the Moon.

		Central Time.		
		d	h	m
Apogee	Dec.	2	5	00 P. M.
First Quarter		5	6	15 A. M.
Full Moon		12	1	46 P. M.
Perigee		14	9	00 A. M.
Last Quarter		19	5	16 A. M.
New Moon		26	8	20 P. M.
Apogee		30	5	20 A. M.

Maxima and Minima of Variable Stars.

[From ephemerides by Dr. Loewy in the "Companion to the Observatory," and by Dr. Hartwig in the "Vierteljahrsschrift der Astronomische Geselischaft".]

MAXIMA.

Dec.	3	S Delphini.
	4	χ Cygni.
	7	S Vulpeculæ.
	11	T Canis Min.
	11	W Cygni.
	12	U Cancri.
	15	U Monocerotis.
	16	V Monocerotis.
	17	S Ceti.
	20	R Lyræ.
	23	R Vulpeculæ.

MAXIMA CONT.

Dec.	25	U Puppis.
	25	U Boötis.
	27	S Scorpii.
	29	S Libræ.
	30	R Hydræ.

MINIMA.

Dec.	2	R Aquilæ.
	3	U Piscium.
	4	V Cancri.
	4	X Boötis.
	5	R Lyræ.

MINIMA CONT.

Dec.	6	V Coronæ
	6	U Cassiopeiæ.
	8	T Virginis.
	15	S Virginis.
	17	R Centauri.
	19	W Tauri.
	19	R Sagittæ.
	21	S Arietis.
	25	T Libræ.
	27	S Aquilæ.
	27	η Geminorum.
	28	V Libræ.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

Alternate Minima.

	h	
Dec.	2	12 M.
	7	11 A. M.
	12	11 "
	17	11 "
	22	10 "
	27	10 "

ALGOL.

Alternate Minima.

Dec.	6	10 A. M.
	12	4 "
	17	10 P. M.
	23	3 "
	29	9 A. M.

λ TAURI.

Alternate Minima.

Dec.	7	7 A. M.
	15	5 "
	23	2 A. M.
	30	midn.

R. CANIS MAJORIS.

Every third Minimum.

Dec.	4	2 A. M.
	7	12 M.
	10	10 P. M.
	14	8 A. M.
	17	5 P. M.
	21	3 A. M.
	24	1 P. M.
	27	11 P. M.
	31	8 A. M.

S. CANCRI.

	h	
Dec.	6	3 P. M.
	16	2 A. M.
	25	2 P. M.

S. ANTLIÆ.

Every third Minimum.

Dec.	1	10 P. M.
	2	10 "
	3	9 "
	4	8 "
	5	8 "
	6	7 "
	7	6 "
	8	6 "
	9	5 "
	10	4 "
	11	4 "
	12	3 "
	13	2 "
	14	2 "
	15	1 "
	16	12 M.
	17	12 "
	18	11 A. M.
	19	10 "
	20	10 "
	21	9 "
	22	8 "
	23	8 "
	24	7 "
	25	6 "

S. ANTLIÆ Cont.

Every third Minimum.

	h	
	26	6 A. M.
	27	5 "
	28	4 "
	29	4 "
	30	3 "
	31	2 "

U. Coronæ.

Alternate Minima.

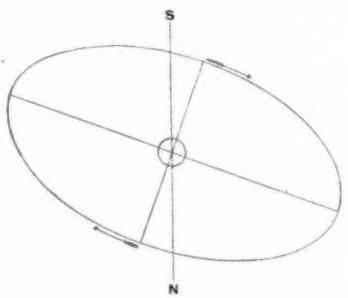
Dec.	1	6 P. M.
	8	4 "
	15	2 "
	22	12 M.
	29	9 A. M.

Y CYGNI.

Alternate Minima.

Dec.	1	6 P. M.
	4	6 "
	7	6 "
	10	6 "
	13	6 "
	16	6 "
	19	6 "
	22	6 "
	25	6 "
	28	6 "
	31	5 "

The Satellite of Neptune.



APPARENT ORBIT OF THE SATELLITE OF NEPTUNE, AS SEEN IN AN INVERTING TELESCOPE.

CENTRAL TIMES OF GREATEST ELONGATIONS.

Period 5*d* 21°.045.

Northeast.			Northwest.		
Dec.	6	5.5 A. M.	Dec.	3	7.0 A. M.
	12	2.6 "		9	4.1 "
	17	11.7 P. M.		14	1.2 "
	23	8.8 "		20	10.3 P. M.
	29	5.9 "		26	7.4 "

In the diagram the central circle represents the planet and is drawn to the same scale as the orbit of the satellite.

PRACTICAL SUGGESTIONS.

74. **The Speed of Light.**—Because the calculations of the eclipses of Jupiter's satellites were about 16½ minutes ahead of their observed occurrence, when the Earth had passed half way around the Sun in its orbit, thereby increasing the distance about 186 millions of miles, the speed of light was determined accordingly. May I ask if there is any proof that the speed of light is the same through distant space as through the atmosphere which envelopes the earth? And if light is retarded by friction in our atmosphere, would it not call for a change of speed through space, to correspond with the former calculations? Also, has the singular coincidence of the same speed of light and electricity—186,000 miles a second—ever been the subject of scientific comment? M. H. R.

Answer.—The reader is referred to the excellent address of William Harkness, delivered before the "American Association for the Advancement of Science," at its Brooklyn meeting Aug. 16, 1894. That address is published, in full, in the October number of *Astronomy and Astro-Physics* and contains answers to both of the above queries. It may be added that the best methods of recent use, in obtaining the velocity of light, get it in the atmosphere at the surface of the Earth by the aid of physical apparatus. This value must be multiplied by the index of refraction of the air to get the real velocity in planetary and stellar spaces which are supposed to be free from ponderable matter.

The last query involves the consideration of luminiferous ether. We have asked one of our foremost physicists to write an article or two for this publication on that theme as related to light, electricity and possibly gravitation. These articles will appear later. In the address before referred to Professor Harkness makes the following statement: "The luminiferous ether was invented to account for the phenomena of light, and for two hundred years it was not suspected of having any other function. The emission theory postulated only the corpuscles which constitute light itself, but the undulatory theory fills all space with an imponderable substance possessing properties even more remarkable than those o ordinary matter, and to some of the acutest intellects the magnitude of this idea has proved an almost insuperable objection against the whole theory. So late as 1862 Sir David Brewster, who had gained a world wide reputation by his optical researches, expressed himself as staggered by the notion of filling all space with some substance merely to enable a little twinkling star to send its light to us; but not long after Clerk Maxwell removed that difficulty by a discovery co-extensive with the undulatory theory itself. Since 1845, when Faraday first performed his celebrated experiment of magnetizing a ray of light, the idea that electricity is a phenomenon of the ether had been steadily growing, until at last Maxwell perceived that if such were the fact the rate of propagation of an electro-magnetic wave must be the same as the velocity of light. At that time no one knew how to generate such waves, but Maxwell's theory showed him that their velocity must be equal to the number of electric units of quantity in the electro-magnet unit, and careful experiments soon proved that that is the velocity of light. Thus it was put almost beyond the possibility of doubt that the ether gives rise to the phenomena of electricity and magnetism as well as to those of light, and perhaps it may even be concerned in the production of gravitation itself."

75. Mr. Gibson's remarks about the beautiful objective which after being taken apart and put together again performed so badly, reminds me of a somewhat similar experience related by Proctor, and also of a like experience of my

own. A friend (of course,) took my glass apart one evening with my foolish permission, and after putting it back the telescope remained unused until the following night. Turning the glass on Jupiter, judge of my dismay on finding the planet surrounded by an immense halo, and with enormous wings thrown out several millions of miles in extent. After some thought I found that the lenses of the objective had been simply reversed. This taught me a lesson; and now, instead of trusting to my own memory or that of a friend when taking the lenses apart, a black pencil mark on the edges renders a mistake impossible.

Another thing that troubled me, was the manipulation of my eye-pieces. After spending a good many dollars, I discovered that the two lenses nearest the eye in my terrestrial eye-piece, which is in two sections, could be utilized when a large field and low power were desired. The field is several diameters of the Moon, and for coarse clusters like the Bee-hive, the Pleiades, the double cluster in Perseus, portions of the Milky Way, etc., it answers admirably; it also gives an exquisite view of the Moon at or near the full. My other eye-pieces push in and out, so that the distance between the two lenses can be increased and the power, therefore, varied. My ⅛-inch and ½-inch I usually keep unaltered, for they must be kept in their one proper position in order to do good work on close double stars; but my ⅝-inch, which on my telescope represents a power of 64, I push out so as to get all powers from 64, 62, 60, and so on, down to 38 or 40. I have also removed the diaphram in this eyepiece, by which I get, of course, a much larger field, and for certain objects it is extremely useful.

Let any young observer, who has spent hour after hour with a 2½-inch or 3-inch glass trying to locate the companion of Polaris make the attempt with an eyepiece such as I have described, or at least with a lower power than he has been in the habit of using. It is also well for him to remember what Mr. Burnham says regarding the companion of Sirius; that on some nights it can be plainly seen with a moderate telescope, while on other nights apparently just as good, there is no more trace of it than if it had been blotted from the heavens. The companion of Polaris is in small telescopes inclined to be "freaky" in the same way; but when at its best it is no test for a 3-inch, much less for anything larger. It does not require separating power, but, as Goethe said about something else, "light, more light." W.

76. In practical suggestion 40, the question is asked whether or no a six-inch telescope will show the shadows of Saturn's satellites on the planet's disc. In Webb's *Celestial Objects*, 4th Ed., it is stated that Titan's shadow was watched by Herschel in 1789 in transit; Gruithuisen saw it in 1833, in 1862 Dawes and several others, including Webb, saw it; it was twice seen at Dun Echt in 1877, and once by Hunt in 1878. Gledhill, Ward and Bazley have also seen it and Banks saw it with 2⅞-inch as easily as shadow of I on Jupiter. W.

77. I want something that will show the positions of the planets at any given time. Will any planisphere show this? A. P.

Answer:—Professor M. W. Harrington, formerly director of the Observatory of Michigan University, Ann Arbor, now Chief of the Weather Service Washington, D. C., a few years ago published a small planisphere which has on the back of it directions for locating the planets at any time during the remaining years of this century.

The Register Publishing Company, Ann Arbor, Mich., will give needed information about that planisphere.

78. How can one procure G. Higgs' Photographic Atlas of the normal solar spectrum, mentioned on page 96 of POPULAR ASTRONOMY. N. F. G.

Answer:—Write to Messrs. W. Wesley & Son, 28 Essex street, Strand, London, England, and prompt attention will be given to all such queries. That old and reliable House acts as our European agent for this publication.

79. Recently the New York papers have published that Louis Gathmann has exhibited a model of his sectional lens telescope and also answered objections made by astronomers Hale and Burnham to the discovery of signs of vegetation on the Moon which he claims to have seen by his new instrument. Has this discovery been confirmed? C. D. H.

Answer:—No, Professors Hale and Burnham do not have much confidence in the theory of the sectional lens for a telescope of any size.

80. What size of telescope is in use at Goodsell Observatory? C. D. H.

Answer: An equatorial of 16.2 inches aperture by Brashear, and an 8¼-inch by Clark.

81. In a large Observatory such as the Lick, how are expenses met? C. D. H.

Answer:—Of the $700,000 left by Mr. James Lick for the erection of the Lick Observatory more than $575,000 was used in preparing the site, erecting the buildings and securing the astronomical instruments for the Observatory. So that of the large gift bestowed less than $125,000 remained for the support of the Observatory after its completion. The Observatory belongs to the University of the State of California, and we understand that the State pays all running expenses and has control of endowment funds through University officers. Professor Holden estimates the annual expenses of the Observatory at $20,000.

82. Can any reader of POPULAR ASTRONOMY help me with a few suggestions for constructing (at low cost) a driving clock for 3-inch equatorials?

I have tried a sand clock similar to that used by Dr. Draper on the photographic refractor of 15 inches aperture, but the sand runs out about 4 times too fast unless the cylinder containing it is about 12-inches diameter (which would be inconveniently large); and if the hole is reduced beyond a certain size, no matter how fine the sand is sifted, it clogs every little while. The R. A. circle is 4½ inches diameter. A. F. G.

GENERAL NOTES

Mr. Lowell's interesting studies of Mars are continued in this number. Considerable more on the same topic by himself and other writers will be found in November *Astronomy and Astro-Physics.*

Jupiter.—Two excellent articles about Jupiter and his satellites have been prepared for November *Astronomy and Astro-Physics.* One about the forms of the satellites by Professor W. H. Pickering and the other concerning the markings on the surface of Jupiter, as observed recently by E. E. Barnard at Lick Observatory. Although both were intended by their authors for our other publication, we have taken the liberty to use them also for this magazine that its readers should have the advantage of them at earliest date possible.

The Progress of Astronomical Photography.—All our readers interested in astronomical photography should read H. C. Russell's paper on that theme which was read as the president's address before the Section of Astronomy, Mathematics and Physics of the British Association at its last meeting. We give elsewhere the first part of it. More will appear later.

E. E. Barnard's Present to the Royal Astronomical Society.—At the June meeting of the Royal Astronomical Society it was announced that Professor Barnard of the Lick Observatory, had sent a series of positives of his astronomical photographs as a present. These arrived in due course; and a very beautiful series they are, well worth a visit to the Burlington House specially to see. There are altogether more than 60 glass positives (10 in. by 8 in., 8½ in. by 6½ in.) chiefly of comets, but including one or two of stars, eclipses, etc. The most remarkable are perhaps those of the Brooks' comet, where the tail is in process of being shattered—as though by some cyclone in space. But all are worth careful study, and it is to be hoped that several, if not all, may be published by the Society in some form or other. The whole of the manual labor of taking the originals and copying them has been undertaken by Professor Barnard personally. At the Lick Observatory manual assistance is no more plentiful than some other luxuries which we have cause to regard almost as necessities.—*Observatory for October, 1894.*

Lawrence La Forge of Alfred, N. Y., has recently ordered of Messrs. Warner and Swasey a 6-inch telescope with a Brashear objective. He is building a small Observatory which he hopes to have completed very soon. He is planning for a spectroscope and other accessories needful for a good amateur outfit.

Telescope for the Illinois Wesleyan University.—An 18½-inch equatorial reflector provided with driving clock, circles and 2-inch finder has been presented to the Illinois Wesleyan University of Bloomington, Ill., by Mr. A. C. Behr a former resident of that city. It is of the Newtonian form, focal length 10 feet 4 in. Some changes will be made in its mounting and a visual and photographic spectroscope added.

A position micrometer and a time transit have been ordered and the 5-inch refractor used heretofore will be provided with apparatus for viewing the solar prominences. Professor M. P. Lackland will direct the work of the Observatory.

Mr. P. S. Yendell, who is a frequent contributor to leading journals of astronomy, especially in regard to variable star literature, has kindly consented to prepare a series of articles for this magazine on the short variables. This will add another feature to the important study of variables given by Mr. Parkhurst as he is not observing this class of stars so far as we know. The first paper by Mr. Yendell will be a general introduction to the subject, with explanation of the use of the mean light-curve, etc., to be followed by a consideration of each star by itself, comparison-stars, mean curve, etc., so that the reader can take up and observe them at once. A chart for such star will accompany the description of it. Mr. Parkhurst will also continue his contributions as heretofore.

On page 459 of this publication it is stated that Tempel was an Italian. That is wrong, he was a German and left Marseilles during the time of war in 1870, but afterwards observed in Italy.

The Moon.—Under publisher's notices we have called attention to the publication of a new map of the Moon, by Messrs. Poole Brothers of Chicago. The map was compiled by Mr. J. A. Colas, of Chicago. It is a work of credit and will be widely useful.

An Exercise Book in Algebra, by Matthew S. McCurdy, M. A., contains 175 pages of exercises intended as supplementary drill work and adapted for use with any text of medium grade; it also states a few definitions and brief rules, and thus becomes suitable for use in general review work on the subject of algebra. At its close is a series of specimen examination papers from leading colleges. The neat binding, excellent paper, and clear type make the volume an attractive one; the exercises in their grading and arrangement are the evident work of an experienced teacher. The book is admirably adapted to meet the need which it has in view. Publishers; Leach, Shewell and Sanborn. Price, 60 cents.

Great Meteor of July 27, 1894.—In the *Astronomical Journal* of October 20 E. E. Barnard gives a fuller account of the great meteor of July 27, 1894, than we have seen elsewhere before. It is so unusual that we give his report nearly in full.

"On the evening of July 27, while reducing observations in my office (at Mount Hamilton) I was suddenly startled by two dull reports like distant cannon or thunder, or perhaps more properly like the discharge of two blasts in a distant quarry. So unusual was the sound in the quiet of the mountains that I hastened onto the roof of the Observatory to find the cause of it. Looking to the east I at once saw a bluish white puff of smoke hanging in the eastern sky. It was then evident that a large meteor had exploded to the east of us.

Noting the time by my watch and estimating the interval since the reports, I made the time of the explosion $7^h\ 35^m\ 13^s \pm 15^s$ Standard Pacific Time. As four other observers made it one minute later, I must have read the minute hand one minute wrong. I therefore adopt for the time of hearing the explosion by me $7^h\ 36^m\ 13^s \pm 15^s$ S. P. T.

As this smoke seemed to be persistent I hurried to the 12-inch and took a series of pointings at the densest mass—a roundish cloud about one degree in diameter, and forming the north east extremity of the triangular strip the smoke had formed itself into. This mass remained visible some time after the other portions faded out, and did not materially change its form.

At first it was easily seen by the finder, but towards the last could be seen only with the naked eye.

The meteor was also seen by Mr. Poole, a student at the Observatory, who noted the time of appearance, as $7^h\ 29^m\ 45^s$ S. P. T. This would give about 6½ minutes for the sound to reach us and would place the meteor some 80 miles distant. The explosion evidently occurred over the San Joaquin valley in the direction of Yosemite.

From several who saw the meteor in its descent, we learn that it consisted of a ball of fire, about as big apparently as the full Moon, which fell vertically downwards. There were two distinct reports, the second being one half as intense as the other and following it by about one second.

Bright Meteor.—As Dr. Wm. A. Duncan and I being outside one evening lately we saw a beautiful meteor, Dr. D. said the most beautiful he ever saw. I did not look at my watch immediately but think it was close to 8:45; the meteor

was of large size, slow motion, some 10 seconds after we saw it; moderate brilliancy, hardly any trail of light, moved after we saw it from a little east of south to about east, from 40° to about 35° above the horizon, course nearly horizontal. It was a pure green large ball which as it reached nearly to the east, shot ahead a smaller pink ball, itself being left behind, and almost immediately both disappeared simultaneously. J. A. H.

Occultation of the Pleiades, Dec. 10, 1894.—We wish to call the attention of our readers to the passage of the Moon by the Pleiades on the night of Dec. 10. This will be rare opportunity to witness a number of occultations of bright stars in one night. They will be visible throughout the United States. The Washington mean times of immersion and emersion of the principal stars, as seen from Washington, is given in our tables, but these times will not be at all accurate for other localities. It is really necessary for each observer to calculate the times for his own place, but we will try next month to give some diagrams by means of which the times may be obtained approximately without calculation.

Sun-spots.—On the morning of May 27 I had the privilege of witnessing the formation of a group of sun-spots, near the Sun's western limb. At 7 A. M. nothing unusual was seen, but at 9 A. M. a circular group of faculæ, about 3′ in diameter, was seen, and on opposite edges of this two tiny spots were seen which rapidly grew in size; and by 2 P. M. three or four others had made their appearance in the same faculæ. Clouds prevented further observation of it that day; on the next day several glimpses were had of it through rifts in the clouds; it was then very near the edge of the Sun's limb. On May 26, 7:15 A. M., a large and beautiful spot was seen almost on the very edge of the eastern limb. There was but a line of light between it and the extreme edge. W. E. SPERRA.

Observations of Venus and Mercury.—May 2d, 1893, civil time, Venus was at superior conjunction with the Sun. June 20th, 1893, forty-eight days after, I saw her with the unaided eye at 3 P. M., and but for cloudy weather I might have seen her some days sooner. These observations were continued through August and September in the evenings, and after our terrible cyclone of October 2d, 1893, observations were made at 12 M. mid-day, and she was visible.

These observations were continued during October and November. After this they were made at 9 A. M. till a few days before she went to inferior conjunction the 15th of February, 1894.

March 4th, 1894, she was seen as early as 7 A. M. and until 11 A. M., and again she might have been seen earlier had not clouds interfered. Since this time she has been seen on all favorable days till she made the meridian passage and on later in the day.

June 30th, 1894, she was seen in conjunction with the Moon at 11 A. M.

Now to sum it all up she has been seen in this cloudy locality with the unaided eye in the day time from June 20th, 1893, to June 30th, 1894, except a few days when she was at inferior conjnnction.

June 4th, 1894 saw the planet Mercury in conjunction with the Moon and through the spy-glass presented a full face; saw him also on the 5th and 6th; clouds prevented any observations till the evenings of the 26th, 27th and 28th, when he was plainly seen with the unaided eye at 6 P. M. and through lens presented the face of a half Moon, and was then three days back from greatest elongation. A. P. H.

Star Names and Meanings.—Richard H. Allen is prparing a book to be titled Star Names and Meanings. We have before us sample pages taken from that part of the book which treats of the constellations. A brief history of the name of the constellation is given first, then follows special notice of each of the prominent stars belonging to the constellation. The Greek letters and the names of the stars are both given in heavy faced type so as to be easily caught on the page by the eye, and the historical meaning of the names is quite fully presented. Nothing is given, in these pages, on the pronunciation of the names of the more familiar stars. This is to be regretted for that is *one* of the lacking things in almost every book about the stars. On the whole these advance leaves promise well and the work will be looked for with interest.

Solid Geometry by Arthur Latham Baker, Ph. D., is a compact, convenient hand-book of the elements of solid geometry. Its notation is new and carefully planned with a view to increased clearness; its demonstrations are brief each being given under the five distinct heads, Notation, To Prove, Constructions, Analysis, Proof. Test exercises are found at the close of each chapter except in the case of the brief closing chapter on conic sections. The author's one aim is to secure for the student a comprehensive, unified, working knowledge of the principles of solid geometry. Publishers; Ginn & Co.

Astronomical Spectroscopy.—Any person interested in a full survey of the work that can be done in astronomy by the aid of the spectroscope should secure the new book called Astronomical Spectroscopy which is a translation of Dr. J. Scheiner's German work on the same subject, published a few years ago. The translation is by Professor E. B. Frost and contains 482 pages, 81 wood cuts and two plates. It is published by Messrs. Ginn & Co., Boston and Chicago.

A full and critical review of this book by Professor J. E. Keeler will be found in the October number of *Astronomy and Astro-Physics*. Another such review by the scholarly J. L. E. Dreyer is the leading article in *Nature* (English), No. 1302, October 11, 1894. His closing paragraph is: "On the whole this English revised edition is a great improvement on the original, valuable as the latter undoubtedly was, and it forms both an excellent text-book for the student and a useful book of reference for workers in spectroscopy."

Principia Nova Astronomica is a new book by Henry Pratt, M. D. of London, we suppose from the preface. The publishers are Messrs. Williams and Norgate, 14 Henrietta Street, Convent Garden, London. We were ill at ease when we opened this book for the first time because we saw so many Latin titles. We said to ourselves, what can the readers of POPULAR ASTRONOMY do with such a book, if they do not happen to known Latin. In his *Præmonitio* the author thinks that astronomers will not believe his theory of astronomical motion set forth in this book, and he gives as a reason, "If they did, the foundations of Science" as they have laid them would be disturbed. That is to say, astronomers are not honest. Are astronomers less honest than doctors? Was Laplace's masterpiece of analysis in mathematical skill a fraud? In this author's eyes what sinners were Adams, Leverrier and Airy. We do not look at the work of those noble men on this side of the water after that fashion.

As far as we have noticed not a single new idea appears in this book to aid the astronomer or the amateur. The author evidently does not understand astronomical methods of work, for evidently the ends of their labors, past or present, are not at all comprehended. What he puts forth in pedantic style as "Astronomical paradoxes," "Conspectus," "principia," etc., has all been thought of before hundreds of times, and as often been discarded as unworthy of record, and yet we have here put up in the form of a very neat book such *Principia Nova Astronomica*. Some parts of this book will have further notice.

PUBLISHERS' NOTICES.

THE MOON.—The map of the Moon, compiled by Jules A. Colas and published by Messrs. Poole Brothers, of Chicago, is now nearly ready for general sale. We have before called the attention of the readers of this magazine to this important aid to lunar study. The map is now quite completed and a copy is before us, and we can speak of it more definitely than before.

The size of the map is 2 feet by 29 inches. It is mounted on heavy paper which is cloth-lined on the back. The background for the lunar disk is a deep blue, which well represents the color of the sky in full moonlight. The diameter of the disk is a little more than 20 inches. It was made so large that all the prominent features on the surface might be well defined in character and be plainly numbered for easy reference. There are nearly five hundred and fifty such features presented on this map, besides a great number of others of less importance that are never named on any map. The markings that are named are so clearly and neatly designated that the map is well adapted for class uses in study or lecture, and admirably well suited for the public or private libraries as a reference map.

After considerable study of the shading on the disk to represent the seas, plateaus, mountains, craters and streaks, we are glad to say that the compiler has more nearly represented the true average color of these features, as revealed by the telescope, regardless of lunar phase, than is found on any similar map of the Moon we know of. Although guided by excellent lunar photographs in getting these slightly varying shades, no one knows better than the compiler how difficult it is to correct the errors of a photographic picture which always makes the seas too dark and the plateaus too bright, so as to get a true relation of color for all. In this we think he has succeeded admirably. In photographing the Moon it is very difficult to get any but the most prominent markings on the bottom of the seas or craters, because a length of exposure that would show such details would destroy all markings on the plateaus by over exposure. But in this map the student will be pleased to notice that a great variety of marked and undulating surface is recorded on every sea bottom. This will make the map realistic in a large sense to those who have the aid of a telescope.

The hardest thing to get in such a picture as this, are the streaks that radiate from the great mountains Lycho, Copernicus, Kepler and some others. They are fairly well given, even better than photographs generally show them at any phase, yet the differences between the systems of Copernicus and Kepler are great even in a small telescope. This difference is of no consequence, however, in our present knowledge of the causes of these great markings on the surface of the Moon.

We especially commend this new map of the Moon to all interested in lunar studies, for we do not know of another so good and complete at so small a charge as that asked by the publishers.

The following notice which was printed in the first number of Vol. II, we wish to repeat, for although a good number have responded to it by sending the desired numbers, there is still need for more: The office supply of Nos. 1 and 2 (September and October, 1893) has been so reduced that we wish to recall a considerable number of copies of these issues, and shall be glad to pay full price (25 cents each) for any which may be returned to us in good condition.

The fact that POPULAR ASTRONOMY subscribers are found in thirty-five states of the Union, and in many foreign countries, together with the fact that these subscribers are largely people distinctly interested in educational matters, should make the magazine a valuable medium for advertising schools, school-supply firms and publishing houses. Advertising rates may be secured from the publisher.

Vol. I, With its five hundred pages of reading matter, twenty-seven full-page plates and varied lesser illustrations, will be sent to any address in the United States or Canada for $2.50, foreign price $3.00. This volume contains seven of our series of monthly star charts, with eight papers on Constellation Study by Prof. Winslow Upton, of Brown University.

MAP OF THE

CONSTELLATIONS

VISIBLE NOVEMBER 15,

AT 9 P. M.

REDUCED FROM SECTION OF
POOLE BROTHERS' PLANISPHERE.

BY PERMISSION.

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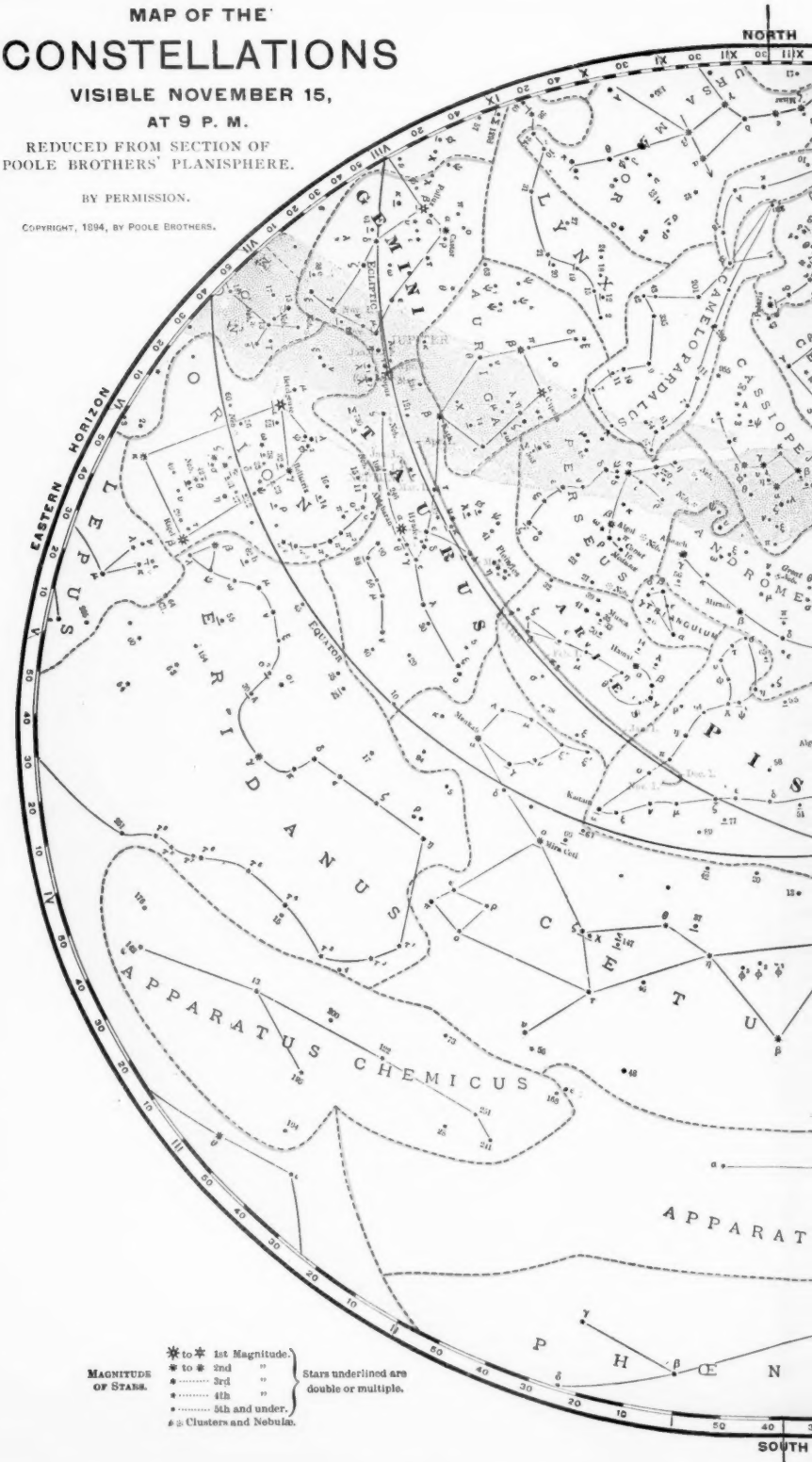
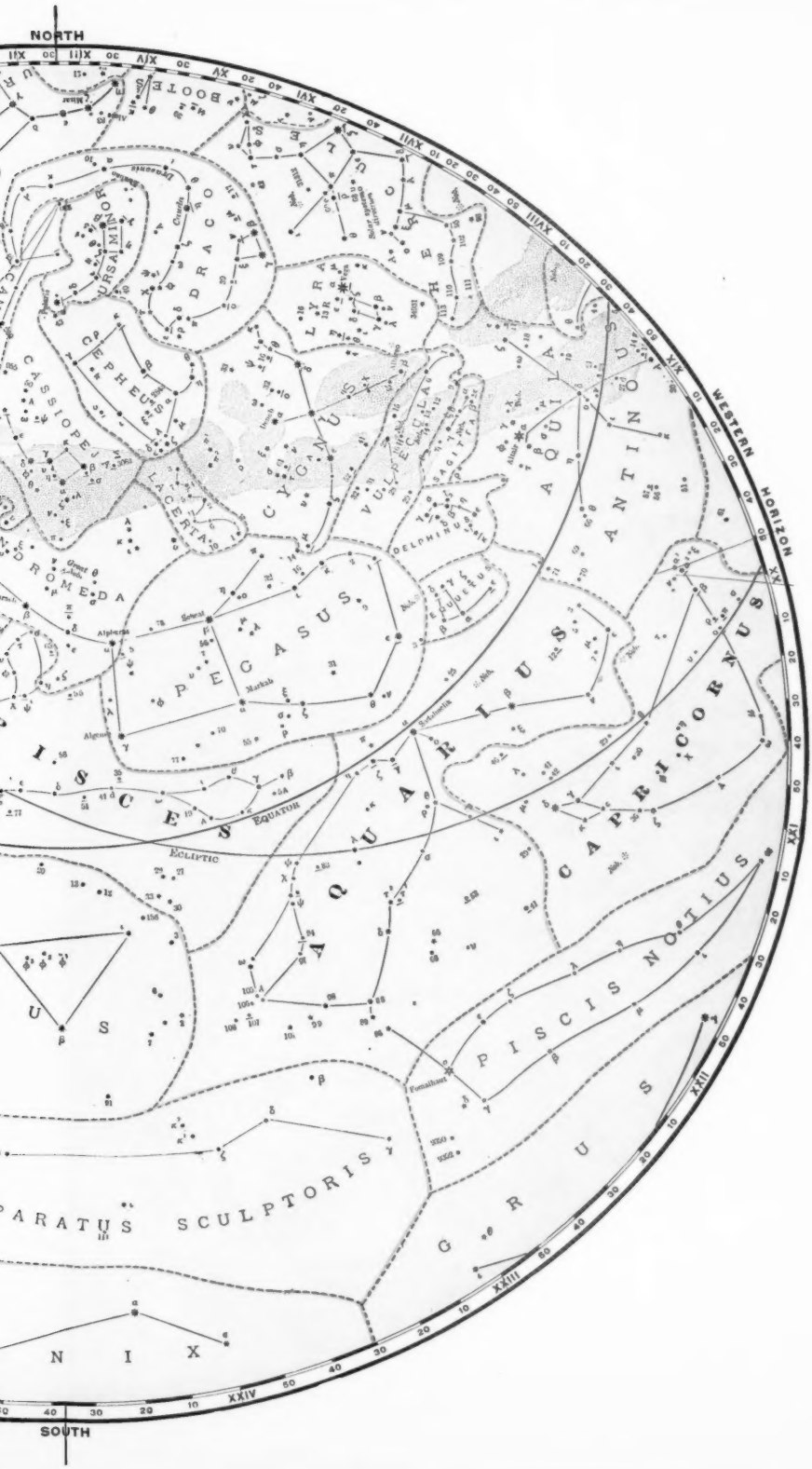


MAGNITUDE OF STARS.

- ✱ to ✱ 1st Magnitude.
- ✱ to ✱ 2nd "
- ● 3rd "
- ● 4th "
- ● 5th and under.

Stars underlined are double or multiple.

⊕ Clusters and Nebulæ.


NORTH
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SOUTH
EQUATOR
ECLIPTIC
BOOTES
DRACO
URSA MINOR
CEPHEUS
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CORONA BOREALIS
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EQUULEUS
VULPECULA
SAGITTA
PEGASUS
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GRUS
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